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MASTERING
POWER PRODUCTION

MASTERING POWER PRODUCTION

The industrial, economic and social problems involved and their solution

BY

WALTER N. POLAKOV

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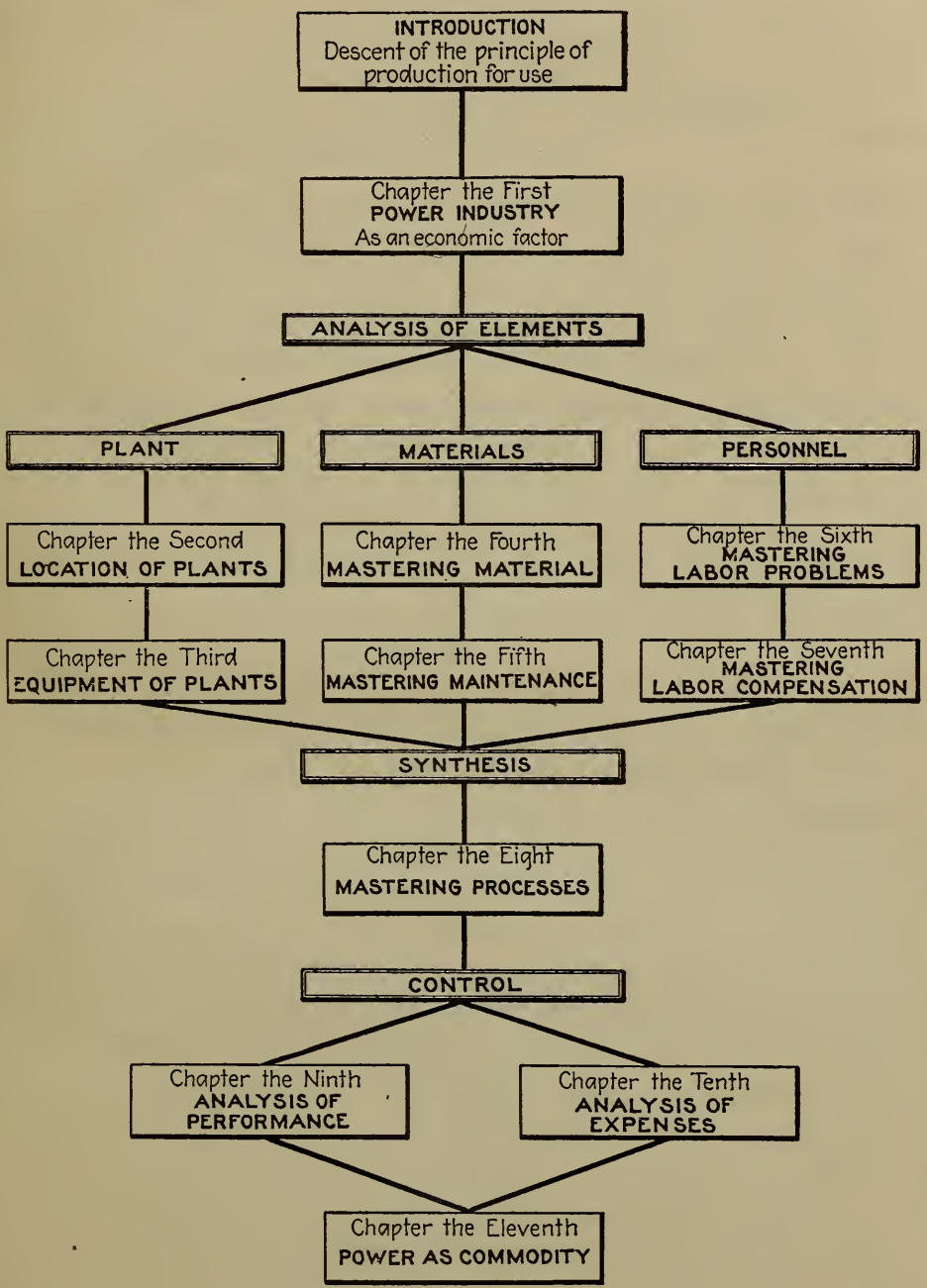
no 1

TO THOSE WHO
PRODUCE FOR THE COMMON GOOD

MASTERING POWER PRODUCTION

DIAGRAM OF CONTENTS



PREFACE

EFFICIENCY in mastering the production of power received little attention under a regime aiming merely at the accumulation of profits rather than at rendering essential service, for it was comparatively simple to transfer the cost of inefficiency and waste to the consumers through price increases.

The bees and the ants of prehistoric periods performed their work in the manner identical with ants and bees of to-day. No expert bee taught the posterity how to produce more honey in less time; no expert ant trained the rest of them how to build hills quicker and with less exertion. Human conception of time is the working force of progress and improvement inasmuch as we seek, learn and teach how to produce greater results in lesser time, thus saving the time allotted us in our lives to live. Moreover, in my discussion of Universal labor, I attempted to show that the cumulative work of past generations lives through the ages and benefits even remotest posterity thus, through creative work of engineering minds, we approach the eternity.

If we apply this criterion to all our work—the human energy expended for production of any result—we must apply it in relation to *time* not only because we live within a limit of time, not even because time can not be created, stopped or extended but principally because the conception of time is distinctively human, is the factor and the exponent of the entire progress of human life.

As the function of motive power is to replace the physical exertion of human and animal labor, the efficiency of its production should be measured as the ratio of human energy spent to that saved, not in terms of money expended and received. If it is true that one horse-power-hour of mechanical energy is equivalent to twenty man-hours of labor there would be no object in producing one horse power of energy by putting to work twenty men. In other words, the labor power expended in the mining, preparation and transportation of fuel, plus that used in converting the potential energy of the fuel into the ultimate form of applied power, plus the labor power worked into all the supplies and materials consumed, and such portion of the labor power as is necessary for construction and replacement of all equipment entering into or contributing to the

generation of the power, must be smaller than the sum total of all the labor power released through the application of this power when generated.

If a coal miner therefore produces 1000 pounds of coal in one hour our thermal equivalent of one *man-hour* is 14,000,000 B. t. u.; if in production of mechanical power we get the use of only 10 per cent of it or 1,400,000 B. t. u., it means that out of the average life of a man we cause him to waste nine years out of every ten years. Again, if we learn how to save ½ of our waste, we either double man's productivity within his life or give him a new lease on life to enjoy and to advance.

Moreover, if our 1,400,000 B. t. u., put to work save only one man-hour work, the whole system is in deadly animal stagnation; but the greater is the time saved by application of this mechanical power to our productive life activities the greater is the progess of our material life, for it means that one man-hour of miner's energy releases on the other end 1+2n man-hour energy, which may mean either that same production can be carried by lesser number of men in the same time or the same number of men working less hours can produce same amount of goods or a greater quantity of goods may be produced within the same time with equal or smaller number of men.

The problem of mastering production resolves, therefore, into mastering of time, or what is the same, extension of human life and happiness.

Yet even this aim alone is narrow and unsatisfactory. Mere "avoidance of starvation" or "chicken in every peasant's dinner pot," appear to-day, in view of the advancement of science and technology, as an uninspiring daily toil. A higher ideal, a more inspiring aim of *self expression* is instilled into the masses of even most downtrodden people by the retrospect of the past struggle for mere animal existence. A desire to create can no longer be suppressed in the human masses. In politics as in the factories it is no longer a full dinner pail that is the goal; it is but an indispensable means for self-expressive creation, for self-projection into the time-to-come.

So long as the stores of natural energy were considered inexhaustible the favorable ratio of labor necessary to harness it, and the labor saved by its application, were easy to secure. However, since the end of these natural resources is in sight, we must learn to use them so sparingly that should we be called to reproduce the sources of energy artificially, the labor required would still remain

smaller than the labor which would be needed to produce commodities without such aid. Laying aside the possibilities of discovery of new forms of energy, or developing more efficient equipment for utilizing the most common source of power—fuel—*our immediate task is to devise a method to make the best use of what we have.*

The technology of such a method of *mastering power production,* as has proven under the most trying circumstances of recent economic, social and political convulsions to be invariably capable of bringing about most desirable results, is the subject of this volume. This method is thoroughly democratic since it substitutes for arbitrariness openly established facts, and voluntary coöperation while rewards commensurate with service take the place of autocratic coercion. It is based on the knowledge of facts; it is carried forward by those who have proved their ability to render service; it aims to benefit the community.

It was not my intention to compile a text book on power engineering; it was rather my care to avoid the treatment of any technical subject which could be found elsewhere in engineering literature; but I could not avoid trespassing in the adjoining fields of psychology and economics, for without familiarity with these sciences the mastery of power production is a futile attempt.

I do not hold that the principles upon which the method is laid out are subject to choice or opinions, for they are based on facts. Yet work of this character can not be complete, or examples may be ill chosen, for it deals with living and constantly reshaping relations and applies to things in process of development.

If this work and its underlying idea will facilitate the solving of some of the problems now in the course of rapid evolution in our industrial relations, I shall feel that my own and my readers' time have not been altogether lost.

The plan of treatment of the subject is simple: The first three chapters state, in order, the economic principle behind the production of power, consider the power industry as an economic factor, present the factors that govern, or should govern, the location of power plant sites, and then take up equipment in particular reference to faults of arrangement and the underlying economic concept.

Then follow five chapters that refer directly to the title of the book; namely; mastering materials; mastering maintenance; mastering labor problems; mastering labor compensation; mastering processes. Two chapters are given over to analyses of performance and expenses, while the final chapter turns to a consideration of power

as a general commodity, as something that is distributed and consumed.

The title of this volume was first used to head a series of articles published in *INDUSTRIAL MANAGEMENT* during 1918. The matter, however, bears little resemblance to those papers, for while the basic idea has been retained, its development has been enlarged and broadened, and its presentation has been enriched by numerous examples and illustrations. In this new working out I am pleased to give acknowledgment to my friend, Mr. L. P. Alford, late Editor of *INDUSTRIAL MANAGEMENT,* for his encouragement and editorial assistance.

WALTER N. POLAKOV.

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MASTERING POWER PRODUCTION

Introduction

THE DESCENT OF THE PRINCIPLE OF PRODUCTION FOR USE

I

". . . therefore the railroads clog up and fires go out . . ."

THE fuel famine of 1917-1918 was expected by those who understood the economic and industrial relations.[1] Those who were called to master national production were forewarned; moreover, it was not in their interests to hinder production, to delay shipments, to jeopardize our army, or to spread misery at home. All that did happen however and the Fuel Administrator summarized the situation that developed as follows: "War munitions, food, manufactured articles of every description lie at our Atlantic ports in tens of thousands of tons, while literally hundreds of ships, waiting loaded with war goods for our men and the Allies, cannot take the seas because their bunkers are empty of coal." [2]

When production had to be speeded up, almost to the exclusion of laws and precedents; when ships were at a premium and a gigantic shipbuilding program was laid out; when we rolled up our sleeves and set our jaws to win the war against autocracy, then it was that factories had to close, railways announce embargoes, no anchorage space was left in New York harbor,[3] and to crown it all, the industries were ordered to cease production for ten days and five Mondays to straighten out the prevailing disorganization.[4] It seemed almost inconceivable that at a time of such acute fuel shortage, about twenty per cent of our transportation facilities were put to the useless task of conveying an excessive amount of ashes in coal polluted by incombustible matters.[5] Such, however, were the facts.

Similar mismanagement reigned supreme not only in the ranks of coal producers but among the coal users as well. The annual

tonnage of coal wasted by mismanagement of power plants is variously estimated by different writers as being between 50,000,000 and 100,000,000 tons per year.[6] The old industrial and economic system demonstrated its incompetency to carry out production and distribution for use. Its organization was designed to conduct business for profit and any other function was beyond its competency. Coöperation, the fundamental prerequisite of democratic organization was found wanting in the regime founded on competition and the best substitute that could be found in the emergency was an enforced coördination. Even such compulsory, arbitrary coördination of efforts as could be devised in the rush of events proved vastly superior to the disorganized, individualistic scramble of unharnessed competition. Said the London *Economist* of British experience: ". . . now, after three years of experimentation it is becoming widely realized that we cannot go back to our old, free untrammeled individualism. We can no longer conduct business, each man for himself, each industry for itself, on the principle of devil-take-the-hindmost. Coöperation under state compulsion has shown us what might be achieved by coöperation under voluntary organization. Inefficient as is industry under government control and management, yet we have seen how very great was our frictional wastage before the war under our old free competitive system. The country, by mobilizing its man and woman power, and directing it to one common purpose, has achieved results which are the wonder and admiration of the world."

What the economist points out is the small measure only of reduction of wastes caused by competitive disorganization in early attempts of the British government at state socialism—directing production to one common purpose—satisfying military and civilian needs. To more fully appreciate the accomplishment one must consider the number of able-bodied men withdrawn from productive occupation and engaged in a large-scale destruction of a goodly portion of the product of the remaining working force. How much greater production may be expected from voluntary coöperation directed toward positive, creative, well-planned, joint efforts, than from enforced coördination, which has rather a negative value of restricting the competitive wastage, can only be conjectured.[7] The initial strength of Germany was due in no small degree to the same paternalistic prevention of dissipation of national efforts which arbitrarily directed all the forces of the nation to one aim of world domination. Yet this very purpose contains the abnegation of the means—coöperation for competition! The Hegelain philosophy

itself should have told them that the only possible outcome of such internal contradiction would be an inevitable destruction from within.

The irreconcilable contradiction between compulsory coördination and voluntary coöperation has too often been overlooked and confused. The aim necessarily determines the choice of means; while a centralized coördination, well exemplified in a military type of organization, is preëminently fitted for the destruction, oppression, and domination of the few, the productive, free activity calls

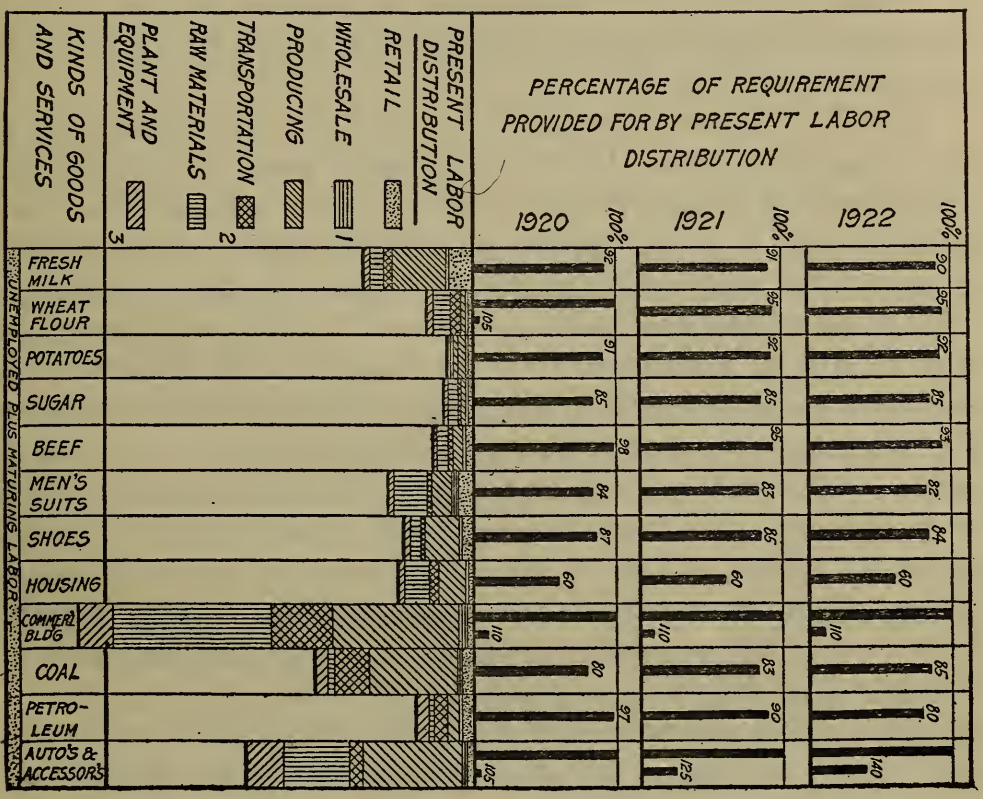

FIG. 1.—RELATION OF DEMAND TO PRODUCTION

From a study made by "Searchlight," based on data of Federal Trade Commission, Council of National Defense and from other sources.

for coöperation of all creative forces prompted by the motives common to all.

Not even half a century ago, the following lines were regarded as a dream of a millennium; to-day, having a mechanism developed by engineers, this Utopia appears as a most practical and inevitable outcome of internal contradictions shattering our entire economic structure. "A system of labor, organized upon a plan of liberty and democratic equality, where each stands for all, and all stand for each, and where the sense of solidarity reigns supreme,—such a system would generate a spirit of industry and of emulation

nowhere to be found in the modern economic system. Nor could such a spirit of industry fail to have its effect both upon the productivity of labor and the equality of labor's product. Furthermore, seeing that all are mutually active, the interest becomes general in the best possible production of goods, with the object of saving labor, of gaining time for the production of further wealth, and looking to the gratification of higher wants. Such a common interest spurs all to lend their thoughts toward simplifying and quickening the process of labor. The ambition to invent and discover is stimulated to the highest pitch; each will seek to outdo the other in propositions and ideas." [8]

Mr. H. L. Gantt felt that the responsibility for the absence of such coöperation rests with "the commercial man, who has not yet recognized that the prosperity of all is directly helped by the prosperity of each. As yet he has no idea of what real coöperation means. His idea of coöperation is that of the herd, whose coöperation is for the attack or defense." [9] Yet, this commercial man, as well as manufacturer or his financier, fall themselves the victims of the organization which is fit only for destruction, whether it is destruction of competitors, of natural resources, or of opportunities. The fact is that the organization for production is as yet in its infancy. We know organizations to sell goods, to uphold prices, to combat unions, to fight legislation, to suppress vice, to enforce tariffs, or to impose our will or belief on others. All productive, creative organizations, as we have so far had, were at the same time inevitably engaged, and to a far greater extent so, in competition between themselves and in combating other antagonistic forces; obviously this diversion of efforts has limited and weakened their productive power.

The suitability of old autocratic forms of organization for their purposes of fight, of oppression, and domination has a successful history; yet with changing forms of life, with new means of production, and with correspondingly re-shaped ideals there can be no assurance that what has been successful under the conditions of the past will be equally applicable at present and will attain the new aims. To the contrary, endless examples give us unimpeachable proof that these methods are no longer fit for our requirements and the longer we practice them the more serious is the friction of internal contradictions, the more appalling is the waste, and the greater the social unrest. The discovery of new forms of organization is a long and painful process, and the people are loath to leave the old familiar and traditional forms of relations; still harder it is

for some to part with their privileges. Moreover, we have as yet no example to follow for, as a well-known engineer has put it: "We have to find new ways and means, accomplish a thing which has never been accomplished before—coöperative organization of a democratic nation." [10]

II

> "The passing of administrative control from the agents of those who would live by their past, to the agents of those whose hands are actually upon the levers, has now become a pressing and imperative necessity." [11]

In the old order of things the master was he who had the title to the means of production: the owner of the land, the owner of the tools, the owner of the slaves, or the possessor of the money to buy the tools, the land, and the labor. The owner of weapons and of skill to wield them became a master of masters, since he had the might to take.

The mode and the purpose of the use of the property remained arbitrary so long as it concerned no one but the owner himself. When however the scale on which the production and exchange was carried out assumed larger proportions the ownership of various large means of production and distribution became collective. A similar process is observed in government. The individual potentate or Ceasar gave way to triumvirates and even republics.

As the complexity of productive operations grew with the development of technique, and the size of the corporate or individual holdings increased, the task of managing enterprises required more individual attention and often more skill than the owner of the property-title possessed. It thus became necessary to delegate the management of certain branches and sections to trained agents, the owner or owners still retaining the right to prescribe the policy and determine the destiny of the enterprise. A parallel transition took place in the management of national affairs. Kings delegated the ruling of provinces to their vassals or governors.

The history of the evolution of industrial organizations has thus been a gradual delegation of managerial functions by the owner to his agent, until the owner became completely relieved of the duties of directing the administration or operation of the property. While it is still possible that the owner may perform any administrative or managerial function, it is equally possible and more common that a person investing his money in an enterprise not only does not

partake in its conduct but even does not know what he owns—his agents administering his estate entirely without his knowledge. While such is the case of a man handling or speculating with various securities, bonds, etc., or heirs often not even knowing exactly how their money is placed, the situation in which many owners of stocks find themselves in different in form only. They may hold the controlling majority of stock and even participate in the meetings of directors without having the slightest knowledge as to the real existing conditions in the enterprise, save the financial reports, and remain entirely ignorant as to technical processes envolved in the production they "direct."

Being thus relieved from active productive functions their interest centers on the question of returns on the investment, irrespective of the mode of using this investment or the social function of the enterprise they finance. These matters are necessarily delegated to the managers of various ranks who are under the obligation to produce the returns to the investors. Thus the whole art of managing industrial undertaking has been reduced to a skillful profit-making; not the making of goods or of commodities, not of rendering service but of securing profits chiefly through a medium of marketing the product. This process in its elementary form appeared to be dependent on the ability to buy labor and materials as cheap as possible and to sell the product of labor applied to material as high as the market will stand. If in the course of production of a commodity a portion of the labor was lost (through loss of time or poor skill) or an excessive part of the material became unmarketable (through poor process or spoilage) the expense of these losses was included in the cost of production as if it had actually been worked into the product—according to a simple reasoning that since such waste did not benefit the manufacturer it must become a part of charge to the consumer.

With the still further development of technique and science even the simplest article required numerous elementary operations in its production. High-speed automatic machinery and the like shifted the importance from the performance of the operation to the coördination of a multitude of various functions and a different form of management became necessary. This need was not realized until very recently and the owners for a long time continued to attempt to delegate the management to men who were supposed to know *how the things are made* though often these skillful mechanics and trained designing engineers knew little or nothing as to *how the productive functions shall be coördinated.*

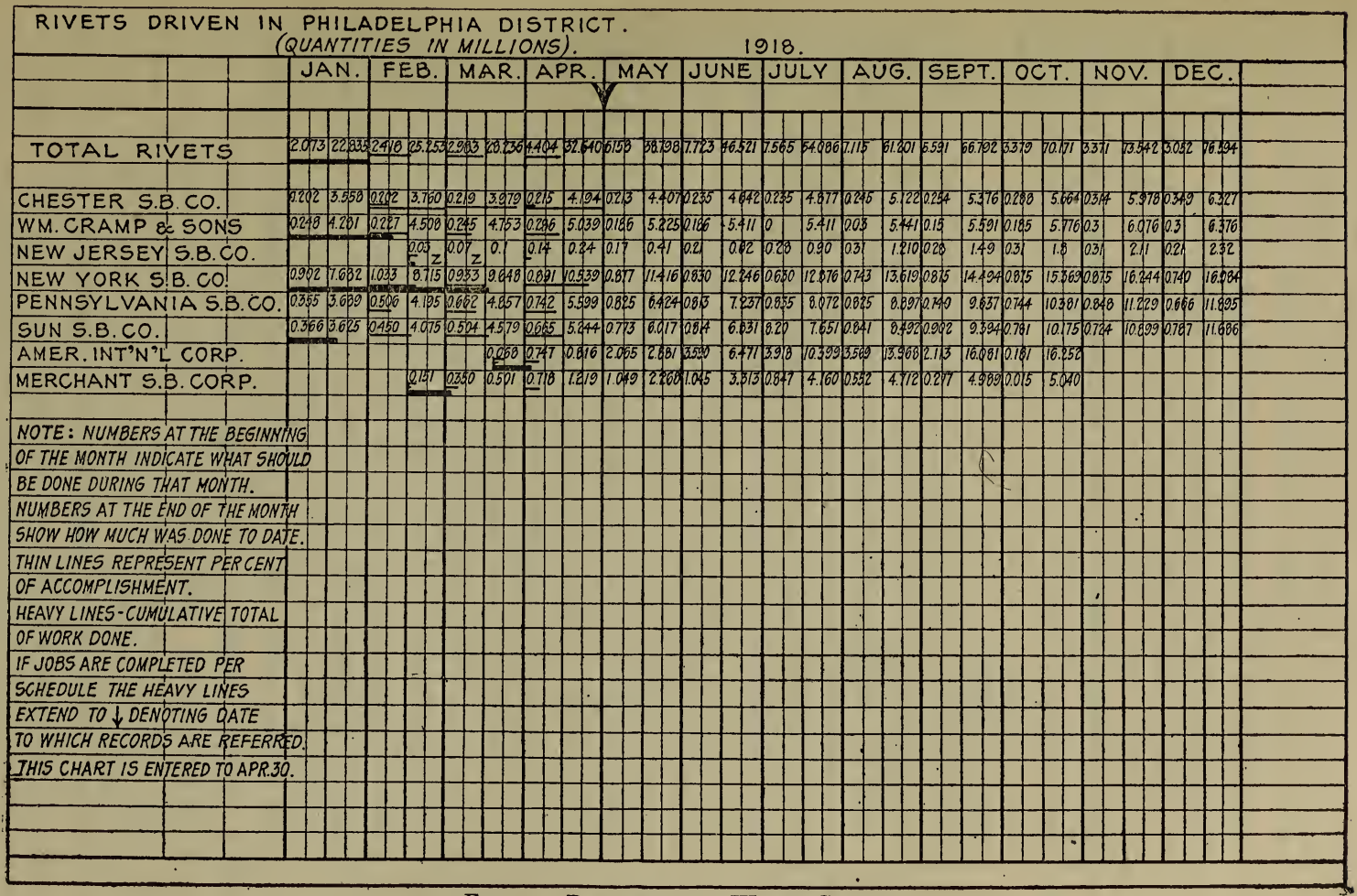
RIVETS DRIVEN IN PHILADELPHIA DISTRICT.
(QUANTITIES IN MILLIONS). 1918.
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
TOTAL RIVETS
CHESTER S.B. CO.
WM. CRAMP & SONS
NEW JERSEY S.B. CO.
NEW YORK S.B. CO.
PENNSYLVANIA S.B. CO.
SUN S.B. CO.
AMER. INT'N'L CORP.
MERCHANT S.B. CORP.
NOTE: NUMBERS AT THE BEGINNING OF THE MONTH INDICATE WHAT SHOULD BE DONE DURING THAT MONTH.
NUMBERS AT THE END OF THE MONTH SHOW HOW MUCH WAS DONE TO DATE.
THIN LINES REPRESENT PER CENT OF ACCOMPLISHMENT.
HEAVY LINES-CUMULATIVE TOTAL OF WORK DONE.
IF JOBS ARE COMPLETED PER SCHEDULE THE HEAVY LINES EXTEND TO ↓ DENOTING DATE TO WHICH RECORDS ARE REFERRED.
THIS CHART IS ENTERED TO APR. 30.

FIG. 2.—PROGRESS OF WORK CHART

Comparison of what was done with what should have been done visualizes the progress of work. The above chart illustrates the falling behind the schedule in riveting, showing that by the first of May the work was two months and a half behind the promises.

Mr. H. L. Gantt in his address in 1912 before the Society for the Promotion of Engineering Education, said: "Until recently the engineer has regarded his work done when he developed an improved machine or apparatus, and proved by operating it for a short while that its capacity was all he claimed for it. It has often been acquired by men imperfectly trained mechanically, but who had the commercial instinct highly developed. Such men usually turn it over to a "cheap" man to operate, and its maintenance is nearly always looked after by a second-rate mechanic, for the commercial man can seldom see why he should have a high-priced man doing repairs. The efficiency of the machine naturally decreases and a factory run on these principles must necessarily be more inefficient still."

Another handicap was frequently encountered in that the management was entrusted to men with predominating ability to buy cheaply and sell dearly, and whose familiarity with the nature of productive processes and mechanism involved was secondary. The inevitable consequence of these shortcomings was the inability to obtain from the plant those results for which it was designed and built. If every one could sell his product at cost plus a desired profit the amount of loss and the degree of inefficiency would not concern him. The market price however is fixed on the basis of the average prevailing cost of producion plus the margin. Therefore, if the losses of any one individual manufacturer are larger than the average in that industry, his margin for meeting financial obligations to others and his own profit may become so small as to make it impossible for him to continue the production. In other words, he can not raise his prices above those of his competitors if he wants the consumer to pay for his losses which are larger than those of his competitors. It is not so in a monopolized industry, as for instance is the case of a single public utility company serving the entire community. Again, if one succeeds in reducing operating expenses below the average considered normal at that time in a given line of production, his margin will increase accordingly. This fact, one may think, should serve as sufficient stimulus to adopt improved methods in order to coin the would-be losses into additional profits, were it not for two economic factors. One is that the selling expenses in most cases are larger than the manufacturing expenses, and the attention of the financial director or commercial man is more readily attracted in this familiar direction than toward the technical possibilities regarding the nature of which he is often ignorant. For this reason the securing of profits was sought

in arbitrary fixing of selling prices, through combines or legal measures, rather than through increase of efficiency of their manufacture. Similiarly, the reorganization of selling methods seems more promising to the commercial mind than improvement of productive methods and in the immediate result (as in case of marketing a certain make of typewriter) is capable of reducing selling expenses sufficiently to forget the manufacturing wastes. While improved method is banned through lack of familiarity with the subject, though the investments needed are usually insignificant, the improved machinery and equipment are costly and increase the overhead or burden, thus they are productive of result only when properly used.

During the past few years it became unmistakably clear that production carried out for profit only, ruins itself in the long run and that the business that reckons with social requirements and meets the needs of society receives the highest reward. Production for profit limits the output intentionally keeping it slightly below the demand in order to maintain favorable prices. High cost of living limits the purchasing capacity of consumers and lowers the demand further. Overproduction results and sends the prices and values downward, throwing at the same time a number of men out of employment, which in turn, tends to lower wages. When conditions are again balanced, the demand gains more rapidly than its satisfaction is provided and the cycle is repeated. This causes a growing insecurity of existence, misery, oppression, degradation and exploitation. As Professor Irving Fisher of Yale said: "American statistics show, such as those of Bradstreet and the Department of Commerce and Labor, wages have risen only about half as fast as the cost of living. If it were true that the increasing demands of labor unions, by increasing the cost of producing commodities, had resulted in a general increase of prices, these would surely have risen more slowly than wages. The facts, however, show that the cost of living has increased about twice as fast as wages, and this seems to be approximately the rule during any period of rising prices. In other words, during rising prices the laborer is the loser. In fact, his strikes and insistent demands for higher wages represent a belated attempt to overtake the advancing cost of living. Labor disputes and demands are thus an almost invariable accompaniment of rising prices, but they are effects of rising prices, not causes." [12]

Another economic factor of great importance is that of a growing necessity to increase the portion of capital invested in

the means of production. This develops the tendency of the rate of profit to fall unless the production is intensified to a higher rate and the output of commodities greatly increased. This necessarily develops a contradiction with the first mentioned tendency: to limit the supply in order to maintain high prices. Consequently such a policy causes a large proportion of expensive machinery to stay idle and accumulate burden which, being shifted on the shoulders of consumers in the form of price added to the goods manufactured with the balance of equipment, works again toward the unbalancing the whole structure limiting the buying power of the society. In other words, to keep pace with industrial progress in order to meet the requirements and competition, improved instruments of production were adopted. Increase of investment is followed necessarily by reduction of the rate of profit, and in order to secure the same or larger earnings the manufacturer must expand the production, that is, increase the investments. This is the process we actually observe in our industrial development. Salvation was sought therefore through raising the commercial profits by increasing the selling prices. This method, although temporarily expedient, eventually overtaxes the purchasing capacity of consumers and creates again a business depression.

The paradox that adoption of improved machinery reduces the rate of profit on the enterprise can be explanied either by the fact that the improvement is merely illusory or that an improper use is made of the improvements. No careful manager would approve a replacement or new installation of equipment, unless study proved beyond any doubt that the advantages offered by such a change are ample to more than pay for the investment. When the cost of production nevertheless increases after an investment is made, it indicates plainly that the method of management does not offer the opportunity to secure the advantages inherent in the new improvement.

Nevertheless, the tendency of the average rate of profit to fall is only a manifestation of the development of the productive powers of society. Automatic action, growing speed and capacity of machinery cause the same number of laborers in the same time to convert a larger quantity of raw and auxiliary materials into product. In other words, the fall of the rate of profit is not due to an absolute but only to a relative increase of the part of capital invested in means of production over that invested in labor. This law, though seldom recognized, is actually followed in our industrial development. It requires an increasing mass of total capital for the pur-

pose of using the same quantity of labor to secure the same mass of profit though at a falling rate of profit. If the mass of profit is to be increased through the introduction of improved machinery (i. e. with corresponding increase of investment) without curtailing the wages or lengthening the working day, the intensity of labor must be increased.[13]

Thus the falling rate of interest acts as stimulus for the adoption of new inventions, the improvement of methods, the employ-

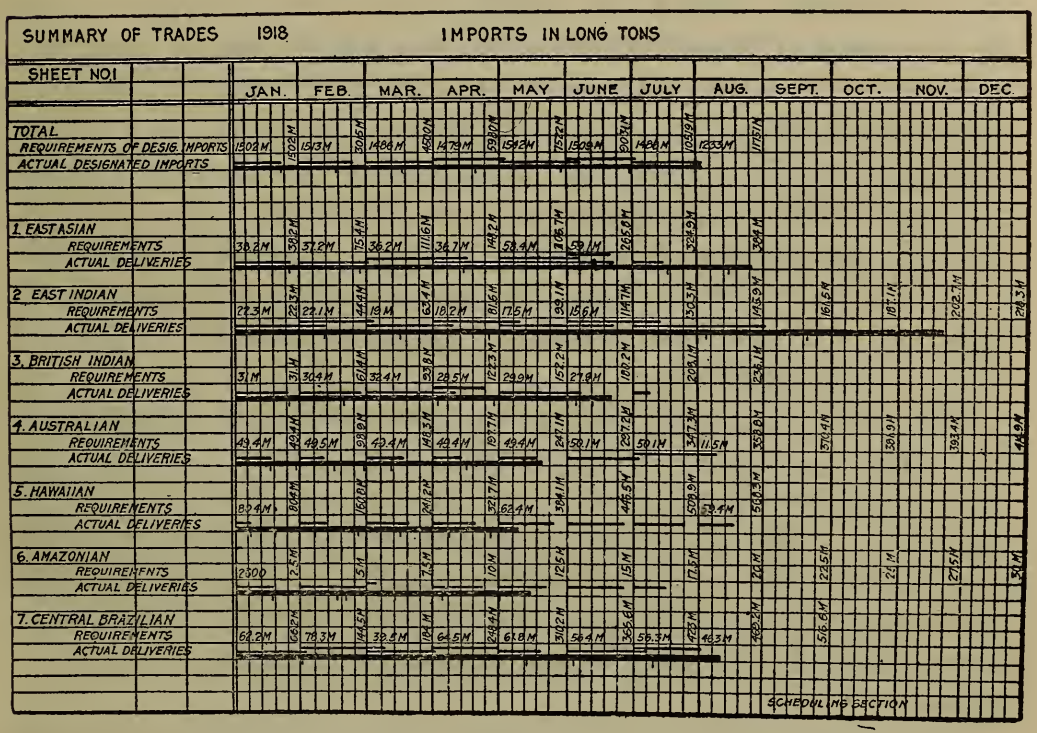

FIG. 3.—RELATION OF IMPORTS TO REQUIREMENTS

U. S. Shipping Board during 1918 used a graphic method of co-ordinating imports to requirements in order to 1—minimize idle movement of useless commodities and 2—to assure the delivery of needed goods.

ment of higher grade men, and the payment of higher wages, while ultimately it tends toward municipalization and nationalization of industries that are socially essential yet unprofitable for private exploitation. This brings us face-to-face with the problem of intensification of labor which has occupied the minds of industrial managers for the last quarter of a century.

For centuries the economists of all but one school had diligently obscured the fact that all wealth is created by labor, yet the common sense of a businessman told him that profit has no other origin but in the ability of the enterpreneur to secure for himself

a larger product of labor than that purchased. Hence, for a long time the chief concern of the management was the intensification of labor-power, or more specifically, the intensification of the personal efficiency of the workman. The work of Frederick Taylor and managerial methods of his school were prompted by the desire to do away with the "soldiering" and the inferior skill of workmen. His elaborate methods of time studies, extra rewards, functionalized bossism and elimination of the inefficient are too well known to be reviewed here. The one-sided application of so-called scientific methods to "speeding up" the workmen made the very name of Taylorism obnoxious to organized labor. Socialists stood alone in the conflict which was brought even to Congress, realizing that this was as inevitable a phase of economic development as the introduction of automatic machinery. To resist the process of intensification of production would be reactionary, but as soon as unskilled introduction of these new methods endangered the health and well-being of the workmen, the isolated instances brought about a vigorous condemnation, not of the principles however but of the mode of their application.

The official organ of the Socialist party stated on August 24th, 1911, that " . . . scientific management must be finally accepted and adopted into Socialism, for only there can it find its complete expression." And also: "When we condemn it (scientific management) as Socialists, we make a great mistake, for it shows precisely how we must proceed in order to make the shop and the factory at once scientific, coöperative and capable of responding to modern needs." [15, 16]

The economic evolution of society goes in a definite direction and it is not within anyone's power to divert or retard its progress. All that can be done is to choose the means to reduce the pains and sufferings caused by the transition period. The engineer must clearly see the way in order to avoid blundering and wandering in the dark. The engineer must assume the role of the leader, since our life is squarely based on the production of the necessities of life which he alone is capable of understanding and controlling as the complexity and intricacy of industrial processes steadily increase beyond the comprehension of a businessman. The prophet proclaims the new goal; but he is the leader who lights the way to those who want to attain it. "If we clearly see that what we are doing is wrong, it would be impossible for us to do so," says René Descartes in his "Oeuvres" (IX; 170).

To understand the principles upon which the new school of

management is to master production and lead the way to the higher forms of industrial and economic relations, a brief review of Bacon-Descartes philosophy is indispensable, since their theory of induction is the basis upon which the creation of modern positive science was made possible. In other words the application of these principles to creative activity is the foundation upon which the new industrial relations can be established.

III

"We shall be saved not by the Aristotelian syllogism but by Baconian induction." [17]

The method of finding out the truth was for Bacon that of pure induction—analysis of a phenomenon in order to bring to light the cause of it, supposedly contained in the phenomenon itself. Says he: "Whosoever knows any form, knows also the utmost possibility of superinducing the nature upon every variety of matter." [18]

In this manner the practical application of discovered truth may begin only after the last step of the theoretical analysis is made. While induction alone, without the inspiration of scientific imagination and use of hypothesis has never led to any discovery, Bacon's method of exclusion and elimination is of immeasurable value. His principles applied to scientific research work destroy all idols of mere authority, time honored opinions or habits. He pointed out two kinds of fallacies: "The proneness to support the preconceived opinions by affirmative instances, neglecting the opposing cases and tendency to generalize from an insufficient number of observations." [19] Those who have read *Shop Management* and *On the Art of Cutting Metals* by F. W. Taylor can readily recognize the influence of Bacon on the conduct of these researches, and the value of this inheritance can not be over-estimated.

The second type of fallacies Bacon exposed and warned us of, are those arising from the influence of mere words on our minds. The great danger of such semi-hypnotic influence can only be recognized when we stop to consider how often the crowd accepts and follows certain formulæ or watchwords, not realizing that they are actually being led in quite the opposite direction. It is indeed only in fact too often the case that the charm of words has retained no meaining under the changed circumstances.

René Descartes put the principle of *de omnibus dubitantum est* as a corner stone for creative analysis and for practical discoveries.[20]

The method of doubt is at the same time a method of abstraction: to obtain truth we must free ourselves by one decisive effort from the influence of custom, prejudice, and tradition which generally obsess our ideas and action to an extent that we are often unable to tell the reason why we do certain things. In practice it resolves into ability to distinguish between an opinion and a fact.

The method of Cartesian school rests upon a proposition that all the objects of knowledge fall into series, in each of which there is a determining element, simple and irresoluble, while the other elements of the group are relative and dependent and can be understood as subordinate to the basic conception. The analysis thus resolved into four groups defined by Descartes are:

1 Truth requires a clear and distinct conception of its object, excluding all doubt

2 The objects of knowledge naturally fall into series of groups

3 In these groups investigation must begin with a simple and indecomposable element

4 An exhaustive and immediate grasp of the relations and interconnection of these elements is necessary for knowledge in the fullest sense of that word.[21]

The method of scientific analysis as applied by Gantt to the problems of industrial management is thus outlined in his own words: "Such an investigation divides itself into three parts, as follows: An analysis of the operation into its elements; a study of these elements separately; a synthesis, or putting together the results of our study."[22]

It now becomes apparent that the method of scientific induction applied to industrial and shop problems constitutes the basis of so-called scientific management or more properly, application of scientific method to management. A French critique of Gantt's principles thus pictures them in the *Revue Métallurgique:* "This is the method employed by Claude Bernard and Pasteur, but Gantt is nearer to the Cartesians. Gantt is too much an American to develop science for the sake of science. The object of scientific investigation is to show to the men a better way to coöperate, in fact to make them happier and to allow them to develop intellectually. . . . This is a point in opposition to German utilitarianism. We have somewhat too much forgotten. Gantt and Taine, the most conspicuous thinkers

of the nineteenth century, conceived the changes which the scientific method will bring into organization of society."

It seems to be superfluous to point out here what wonderful progress has been made in all branches of pure and applied science since it was based on the principles established by Bacon and Descartes. The chemical, electrical, and mechanical discoveries made an enormous production possible with a simplicity, ease, and speed unbelievable even a few years ago—talking across the ocean, seeing through flesh, synthetic creation of food, air travel,—all exceed the wildest imagination of Jules Verne and tales of a Thousand and One Nights.

Reconstructed on the sound scientific basis, the art of management of shops and plants gradually shifted the responsibility from the workmen to the manager. It is the manager who under this regime is expected to know:

1 What to do

2 When to do it

3 How to do it.

As long as the owners continued to trust the management of their affairs to men trained as lawyers and bankers, who still base their claims "upon information and belief," the wide application of the scientific type of management was impossible for the want of necessary training in the use of scientific analysis.

The interest in scientific management movement at the beginning was limited to an imitation of forms and isolated features overlooking the basic principles. Room for improvement however was so large that even untrained imitators met sometimes with a measure of success. The results obtained by "efficiency engineers" and "stunt peddlers" while demonstrating clearly what an enormous wastage was going on in our industrial disorganization, created a demand for results rather than for proper methods which necessarily will be beneficial. The struggle to make workmen personally efficient soon met however with an organic obstacle on its way to intensification of production.

While "efficiency engineers" were talking about how to save fractions of a minute wasted by workmen, the management cared little if half of the plant equipment remained idle, due to one cause or other. It was not generally recognized that to keep the plant idle cost money, usually a great deal more than to let the man stay idle. Somebody had to pay for the rent, for all forms of overhead ex-

penses or burdens, yet our financial structure devised vicious methods of accounting which distributed the expenses of non-use of productive capacity on the product. In other words, as the author has pointed out at a meeting of The American Society of Mechanical Engineers,[23] the common practice is "to charge against the cost of the product the cost of over-equipment and mismanagement, thus imposing on society the penalty for tolerating these conditions in the industries."

The greater the efficiency with which the working portion of the equipment is used the larger is the burden imposed by the idle portion of the plant, and usually the remedy is sought in the advancing of prices of the commodities. Higher prices, however, soon overtax the purchasing power of society, and demand falls, leaving still more equipment in idleness.[24] The problem thus turned toward "how to make management efficient." It was realized that "our industrial scheme will not be rounded out until we have a means of measuring the ability with which those at the head of the business perform their functions, that is at least as good as that which we use to measure the efficiency of the operative."[25]

In the closure of my paper before the Taylor Society in 1916 I said: "We have been in the habit, for a number of years, to blame workmen, to blame firemen and engineers for poor results. I am convinced that this is the gravest mistake. Fifteen years experience in this industry, which has put me in touch very closely with a great variety of power plants, has proved to me that the average fireman knows more about power engineering and . . . has a cleaner conception of what contributes to the success of the business than have some members of the Board of Directors";[26] and at the New York meeting of The American Society of Mechanical Engineers on January 11th, 1916, the author presented a paper which offered a *method of measuring the efficiency of the plant management,* in the conclusion of which, he said: "If the principles and methods are right, the results will necessarily be the best obtainable . . . ."[27] And in addition to these the series of paper presented before various engineering societies[28] during the last few years have every time more persistently and clearly exposed the necessity and proposed the possibility of measuring the managerial efficiency.

Another far-reaching principle has come to light still more recently, namely that of coördination of the productive functions not only within a plant but among various plants. Lastly, under the stress of conditions imposed by the war, the function

of distribution and selling products was separated from purely productive functions and in many instances taken care of on a coöperative basis or by the State.

The social importance of these three events can not be over-estimated:

1 Recognition of non-use or partial use of means of production leads to the possibility of further vast increase of productivity

2 The method of coördination of productive functions on a national (between plants) or international (between countries) basis eliminates duplication of efforts and losses and thus further enormously increases productivity

3 Coördination of distribution does away with enormous loss of efforts in transportation and marketing while limited competition liberates an army of sales forces for productive occupations, does away with disorganized overproduction, industrial depression, unemployment, and hoarding, and assures to the consumer equitable prices and a more liberal satisfaction of wants.

True enough, all those possibilities are far from being fully realized, yet the recognition of the principles and the discovery of the means whereby the control may be secured, mark the dawn of a new industrial era.

For over half a century the State and business helplessly floundered trying to lay out budgets, industrial programs, to organize the transportation, to determine true demand for commodities, etc., but the anarchy of production unguided by accurate knowledge of *what* is wanted and *where* and who can supply the demand and *when,* continually frustrated all the well meant attempts to introduce even a semblance of order into our industrial life. Ordinary statistical reports, whether Governmental or private like these of Babson or Bradstreet—were unable to put in order the confusion of disorganized production and distribution, and their forecasts were at best guesses with semblance of reason dependent on one condition: that the past tendencies will not be upset by future unforeseen influences. These statistics of production and commerce are frequently inaccurate; firstly, because the data collected by private organizations are in the most part incomplete; secondly, because it is often against the immediate business interests to make public

such data the concealment of which may be profitable to some individual or group; thirdly, such elements as speculation, conflicting interests of thousands of private producers and merchants step in and sometime render conclusion from incomplete data valueless; finally, and this is the most vital condition, the prognostication may be reliably accurate only when mutuality of interests sets a definite task for accomplishment before each party. The experience of industrial crises and panics teaches the lesson that they are caused chiefly by blind unorganized production, carried on without a knowledge of volume of supply, of sales, of demand for goods on the world market. Benefited by these lessons large manufacturers and merchants combine, join in trusts and rings, partly for the purpose of steadying prices, partly for the regulation of production guided by combined knowledge of probable demand and distribution of orders among themselves according to existing facilities to fill them at the lowest cost. The benefit thus accrued is not always to the advantage of the public as under such condition it is possible to maintain the prices at a higher level than if the manufacturers and merchants were engaged in a competitive struggle among themselves.

When, however, the interest of all is supreme, as in the case of the Allies during the World War, those broader National or even International interests are taking precedence over the private gains. Production under such condition is carried on for the satisfaction of common needs, not for the profit of private individuals, and the demand for a better working mechanism than the old-fashioned statistics has become imperative.

The coördination of demand with supply and production control in accordance with the task set on the basis of known requirements is the recent field opened for industrial administration. When it has been applied to munition production it not only increased production but enabled shifting of parts of orders from plants poorly fitted to ones better adapted; when used in connection with Emergency Fleet work it disclosed delays and inefficient management in some yards from which the contracts were therefore taken away to prevent loss of time and the people's money; practiced in the Shipping Board it has revealed not merely unproductive loss of time by ships at docks and at sea but the fact as to *what* commodities are wanted, and *where* and *when* certain ships are ready to sail.

The application of the same mechanism to labor problems

would help to eliminate unemployment and labor shortage; in railroading the opportunities are even larger than in navigation; in public utility, the fuel problem, farming or any other activity the result can not fail to show once more that organized coöperation even with the existing methods and facilities is capable of producing enormously greater wealth than it was dreamed could be produced. For the time being it appears that the main task of industrial administration is not to devise new appliances, not even so much to increase whatever degree of individual efficiency we have, but to learn how to make use of the productive means and forces we have already developed for the common good.

That the new order of things can not come to existence without such an organ of information and that it would be inoperative unless the proper working mechanism is devised was conceived nearly fifty years ago, although the chief hope at that time was laid on statistics. How clearly this was realized by an economist the following passages may prove:

"The principal thing to ascertain is the number and the nature of the forces that are available, the quantity and the matter of the means of production,—the factories, the workshops, means of transportation and communication, land—and also their productivity. The next thing to ascertain is the quantity of supplies that are on hand and the extent to which those can satisfy the wants of society. As to-day the State and several municipalities yearly cast up their budgets that thing will then be done with an eye to all the wants of society. . . . Statistics here plays the chief *role*: they become the most important subsidiary science of the new era: they furnish the measure for all social activities."

"If for instance the demand is statistically established for bread, meat, shoes, linen, etc., and, on the other hand, the productivity of the respective plants is equally known, the *average daily amount of socially necessary labor is thereby ascertained* (*i. e.,* task is correspondingly assigned to each plant stating how much product must be turned out daily). The figures would, furthermore, *point out where more plants for the production of a certain article may be needed, or where such may be discontinued as superfluous, or turned to other purposes.*" [29]

The unprecedented requirements for a speedy production and elimination of all kinds of waste spurred by the World War can not be diminished during the period of reconstruction and the

experiments carried out in a limited sphere of Governmental activities must of necessity be extended over the entire industrial world. Unless the League of Nations is established on a sound principle of economic coöperation free of tariff protection and limitations of export and migration of labor, the international competition will remain. In the world market that nation gets ahead soonest who sells cheapest and this can be done only by producing in the most efficient manner. In any event we are on the eve of a new industrial era toward which every day makes further progress. The changes of utmost social and economic importance are taking place often before the majority affected by them have time to realize their significance. There is, however, only one thing of which every thinking man is certain—that the new wine must not be poured into the old bottles and it is the task of the engineers to provide these new bottles—that is, the methods and tools that can serve the people best in attaining their highest aims.

Chapter I

THE POWER INDUSTRY AS AN ECONOMIC FACTOR

THE wonderful development of the United States from the obscurity of a remote English colony into a dominating World Power is due to three main facts: conception of the idea of *democratic coöperation*; realization of the paramount importance of the *time factor*; and application of *power* to save time and efforts so that the production of necessities of life will be rapid and easy enough to leave time to live and advance.

Entire industrial activity depends on the sources of power. With the exception of an insignificant volume of work done entirely by hand, all production is dependent upon power driven machinery and with further development of automatic processes and equipment augmenting muscle power of men and animals, power generation will assume a still greater importance. Similarly, transportation by land, water, and air; communication by rail, wire, and wireless; hygiene, both communal and personal; comfort, safety, education and even medicine and art are becoming more and more dependent upon the power to render the gifts of nature of use in the service of humanity.

The most spectacular and rapid industrial advancement of this country, out-distancing even our unparalleled opportunities in the agriculture, forestry, and animal husbandry, was chiefly due to the unlimited fuel deposits combined with other rich mineral resources. In other words, the abundance of conveniently available power made it possible to make this country what it is to-day.

The whole progress of the last century both in mode of production and of living was made possible only after the man-power was replaced by the harnessed incarnate energy of the universe. Ox-plow was replaced by a power-tractor; mule team and coach by steam and electric trains, automobiles and aeroplanes; artisan's tools by modern automatic factory equipment. Small as it may be, the factory power plant or public utility central station is the life center of a community. Stop the supply of motive power and men with their machines are thrown out of their productive occupations, groping in the dark, frozen, starved, without means of communica-

tion, impotent to conduct life according to the customary standard yet out of habit to live in the great-grandfathers' fashion.

This changing of mode of production, notably since the time of Papin, Newcomen, Watt, and Stevenson and now continued by the nameless inventors employed by Edison and other entrepreneurs has indisputably resulted in an enormous increase of the productivity of labor.[30] While it is true that half of our productive equipment remains idle due to poor managerial methods or, more properly, due to our industrial and business system, while the other half is used only at something like half of its productive capacity, as frequently stated by most competent and well versed investigators, the fact that our industrial output of to-day is vastly larger than that of two or three decades ago, is chiefly due to the growth of industrial uses of electrical power. Reporting on the electric power supply in Great Britain, the Reconstruction Committee[31] stated: "In considering the future it may, we think, be assumed not only that the output of industry will continue to increase, but also, that the use of mechanical power will, even more rapidly, continue to replace, or at least supplement, human labour. It is obvious that improvement in the commercial prosperity of a country—that is to say, the average purchasing power of the individual[32]—depends on increasing the output per head. If the wages be raised merely by increasing the selling price of the goods in the home market there is no real advance, and to increase the selling price of the goods in the neutral and open markets of the world is hardly possible in view of international competition. The only way to increase prosperity is to *increase the net output per head of the workers employed.*" That this increase of the net output per man is in some direct proportion with the use of power in industry seems to be well substantiated by our census as well as British data (see Chapter XI). The above mentioned report continues: "In the United States the amount of power used per worker is 56 per cent more than in the United Kingdom if we eliminate workers in trades where the use of power is limited or even impossible, we shall probably find that in the United States the use of power where it *can* be used is nearly double what it is here. On the other hand, not only are the standard rates of wages higher in the United States but living conditions are better. There is little doubt that in the United States the average purchasing power of the individual is above what it is in this country, and that this is largely due to the more extensive use of power which increases the individual's earning capacity. The best cure for low wages is more motive power. Or, from the manufacturer's point of view,

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SYMBOL	DEPARTMENT OR MACHINE CLASS	PERCENT OF CAPACITY USED ON Day TURN (10 20 30 40 50 60 70 80 90)	TOTAL EXPENSE OF IDLENESS	DETAILS OF IDLENESS EXPENSE DUE TO: LACK OF ORDERS	LACK OF HELP	LACK OF AND POOR MATERIAL	REPAIRS	POOR PLANNING	REMARKS
R G	G		$23 67	5 10	18 57				
R S	C		13 24	13 24					
R S	S 1½		26 88	9 65	10 15		7 08		
R S	S 1⅜		25 14	25 14					Now Scrapped
R S	SO		31 45	31 45					
R S	R		4 27	4 27					
R S	R1		7 24	7 24					
R J	1-i		13 50	13 50					
R J	2-i		23 07	14 56	2 24		6 27		
R J	5-i		20 71	20 71					
R W	W		23 91	23 91					
R B	RW		16 64	16 64					New Machine now in Operation
R B	SPW		30 48	30 48					These will be Scrapped
R B	Boxers		5 54	5 54					Total Expense $664.80
	Average								
	Machine in Storage		32 83	32 83					
									APPROVED BY
			298 57	254 26	30 96		13 35		J. W. White SUPT.

FIG. 4.—IDLE PRODUCTIVE CAPACITY IN A FACTORY

On the average of the month on record, only 36% of production was carried out by this factory; some of the departments doing only 5% of the work, none producing more than 72% of possible output. Obviously a power plant serving this factory has poor load and machine factor, low efficiency and high idle overhead expense.

the only offset against the increasing cost of labour is the more extensive use of motive power. Thus, the solution of workman's problem, and also of his employer, is the same, viz., the greatest possible use of power. *Hence the growing importance of having*

available an adequate and cheap supply of power produced with the greatest economy of fuel."

That the electric motor drive is the best known way of utilizing the power in industry and that electric traction particularly on trunk lines is the most economical means may be admitted now without bringing here argumentation of well-known facts and experiences, *thus our problem is not so much how to apply and use power in industry and transportation but how best to generate the electric power.* The successful solution of this problem, of efficient and economical generation of power, is therefore more than one of the industrial problems, more than a vital issue of the period of reconstruction—it is the foundation of future economic development of society.

The widespread, extensive application of mechanical and electrical power to industries has so far exhibited two tendencies: increase of productivity and corresponding increase of wage-rate. The question often asked in this connection from both sides—capital and labor—is the same, though emphasis is laid on different phases of it. How will it be possible with the increased production to maintain the rate of profit and how will it be possible to avoid the periodic business depressions with co-incident unemployment? The answer to this is that *we never had over-production but we had from time to time overtaxed the purchasing capacity of the majority of the population.* We can not talk of overproduction co-existing with a large percentage of recruits whose physique is so undermined by bad living and working conditions as to render them unfit for the army, with underfed children of which we have school records, with charitable institutions having so much to do, with unsanitary, crowded tenements breeding and spreading epidemics, with police and detectives guarding moral and private property,—for if it were actually an overproduction it would mean that more than all needs and wants are already satisfied. But the goods and commodities remain uncalled for and unconsumed because the people have no money to pay for them and factories are closed to further reduce the output; this in turn swells the army of the unemployed that are forced by privations to underbid each other in order to secure any means of existence. In other words, the danger lies not in the increasing production by one means or other but in the system of distributing the product. Without any intention to be paradoxical, we must conclude that in order to do away with the ills of "overproduction" we must still further increase production, so that through a large increase of productivity we could throw on the market a

tenfold or larger quantity of commodities. These must be sold and in order to be saleable, the price of commodities must be as near the cost of production as possible and the cost of production must be as low as the perfection of methods and elimination of waste can make it. The low-priced commodity readily finds a market as in the process of producing this commodity, a large number of workmen were

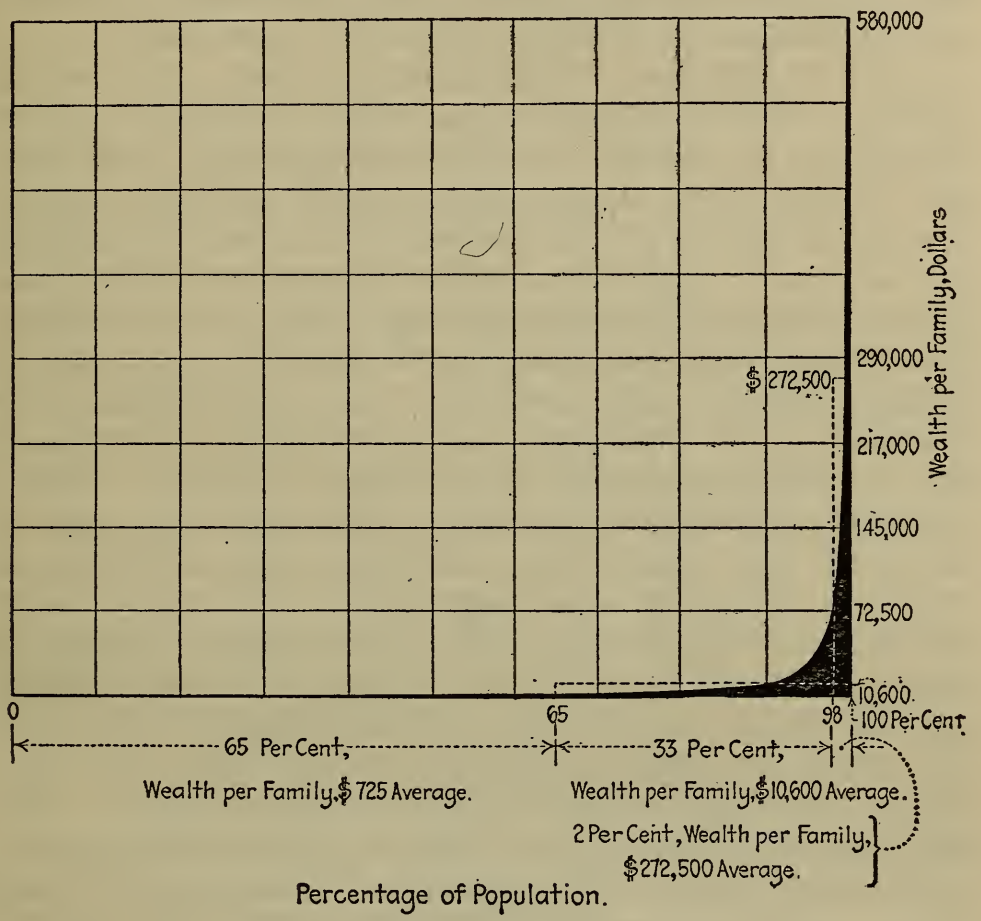


FIG. 5.—DISTRIBUTION OF WEALTH

Computations have been made on basis of statistics of wealth and income to show the distribution of it among the groups of population. (Courtesy of J. W. Ledout and Engineers' Club of Philadelphia.)

engaged at sufficiently high wages. Then, while the rate of profit might be still lower than before, the volume of business is greater so that the amount of profit is either the same or larger than before. Such falling rate of profit is actually observed in all industrial countries and the more developed are the trade and technical processes, the more pronounced is the reduction of the rate of profit. The so-called industrial paradox, first discussed and explained at the International Congress in London in September, 1865, "that *high-*

priced labor may produce cheap, and low-priced labor may produce dear commodities, loses, therefore its paradoxal appearance." Indeed with highly specialized, complicated and expensive machinery the cost of production per unit manufactured drops as wages of the operatives raise, and the attempts to reduce wages has invariably resulted in an increased cost of labor per unit produced not to mention the enormous damages and losses caused by inexpert, indifferent usage of often delicate machinery by low-priced attendants.

In the *Transactions* of The American Society of Mechanical Engineers [32] we find a highly important and as we all know a typical illustration of an enormous loss of productivity through mismanagement. Figure 1 gives another glaring example and picturesque explanation of why we produce less than we can and pay labor less than we should. That such an order of things tends to undermine the economic balance of the country may be seen from the diagram, Figure 5, based on the data of the United States Census representing the distribution of wealth per family. Mr. J. W. Ledoux in his presidential address at the annual meeting 1916 before the Engineers' Club of Philadelphia summed up the situation as follows: "Careful investigation show that the wealthiest 2 per cent of the people of the United States received almost as much income as the poorest 50 per cent and own far more wealth than the other 98 per cent." [33] Then again, the diagram Figure 6 shows the steady rise of prices of ten staple commodities based on the average price from 1890-1899 taken as 100—the authority for it is the Bulletin of the United States Bureau of Labor Statistics No. 114, April 4th, 1913. Such were pre-war conditions which might be termed "normal." These three illustrations show only too clearly the gradual deterioration of the purchasing capacity of the population. To expect that a return to these conditions after the war is either wise or safe would be folly. Yet, since the nightmare of the War is over, these conditions continue in the same direction. The increased productivity of labor with correspondingly increased buying and consuming capacity of the majority of the population is an issue that can not be dodged.

In the course of economic readjustment the extensive application of power in manufacturing and other operations would play an important double part. Firstly, it means higher wages in industries using more power per workman than in those using little or no power, and secondly, it develops conditions, the escape from which is open in one direction only—*increased production of cheap commodities co-incident with higher wage rates,* and as this increases the purchasing capacity of the country and increases home-consumption, it grad-

ually eliminates the necessity of conquest of foreign markets by wars. The accomplishment of this program would not be possible without fully developed mechanism making such changes practicable. By this we do not understand the mechanical equipment, which has already attained a sufficient degree of perfection to produce the desired results *if* properly used but what we do mean is the method of the utilization of existing means and the economic relations requiring this. These three elements are organically interconnected—it is futile or even wasteful to have good equipment if the proper method of its use is not known but the best of method never could find acceptance unless the results are economically desirable. Similarly, the clearest conception of the economic problem requiring an immediate solution could not be of any practical value unless means and processes are at our command.

Heretofore, the sales department, or contract or new-business department was considered the most important in industry as well as in public utilities, because the production was carried out primarily for sale, not for use or service. How efficient was the utilization of existing plants, how good were the methods, how satisfactory was the service and what effect it all had on the economic welfare of the community or the development of the country did not matter much so long as the sales were good and contracts were closed at a high price. If the plant was idle to a large extent, so much the better as it meant provision for new business, the overhead charges being borne by the customers in any event; if the operating efficiency was low—it caused no concern, for the customer was charged for all the expenses incurred in production, whether they were necessary or not, and so if two pounds of coal were sufficient to generate one kilowatt hour but four were used, the company did not suffer; it was up to the consumer to pay cost plus.

During the war, a new criterion had to be accepted: not the sales, not the accountant's balance, but production. Was there enough power to run the industries? Was there enough coal to generate the power? How many kilowatt hours may be delivered from a kilowatt of plant capacity; how many more kilowatt hours may be generated per ton of coal, and similar questions gained in importance. Yet the methods were unfamiliar to those at the heads of the businesses. More output, more power meant for them merely purchase of more machinery; better economy was understood by them as installation of new, improved equipment. So one public utility company after another filed in line asking from the Government, the people's money for more plant, for better plant; one asked

$20,000,000, another $15,000,000 and so on. It apparently did not occur to men accustomed to sell and speculate that there might be other ways than borrowing money when more goods are needed.

It is truly astonishing how little attention has been paid to the matters of managing and operating the power plants. All that has been done, said or written was confined almost exclusively to a limited field of improved equipment. Once the plant was equipped, it was assumed as a matter of course that the result will be commensurate with the salesmen's promises. Three typical charts, Figures 7, 8 and 9 show coal losses in poor, medium and fair plants. That the *authority to invest the money involves the responsibility for the results* was only too often forgotten; to take the pains of studying things over which one already has a measure of authority was frequently considered superfluous; besides we were in the habit of doing the things first and watching the consequences afterwards. If these were bad, we were quick to blame it on contractors, on employees, on conditions, on anything but our own lack of thorough knowledge indispensable for mastering the production.

Perhaps the weakest point in our industrial structure is our meek submission to the arbitrary power of those who possess things. For the reason of their having controlling financial interest in the enterprise, they assumed the authority not only to dictate the policy but even to interfere with the technical details of managing the plants. When the man connected with financial institutions selects plans and specifications for equipment, chooses sites, contracts for supplies, fixes rates and wages, etc., the chances are at least equal that the interests of the community and the purpose of service will be obscured by other considerations. In this connection it is quite reasonable to place a great deal of responsibility for errors in judgment at the door of the accounting and statistical systems which generally overlook the facts of greatest importance for reaching a correct decision. That *our accounting systems are devised to warrant the income on the title or investment and not to represent actual facts* concerning the operation of the property and the value of the service, need not be proven here. The prevalent practice of valuation of the physical property renders simple but conclusive proof that claims for income are generally made on a basis of the money invested, irrespective of whether any good use is made of this investment or not.

While the interests of the country, that is of the people, demanded not only an abundance of cheap power but the efficient operation of those plants which we already have, the engineer remained in a

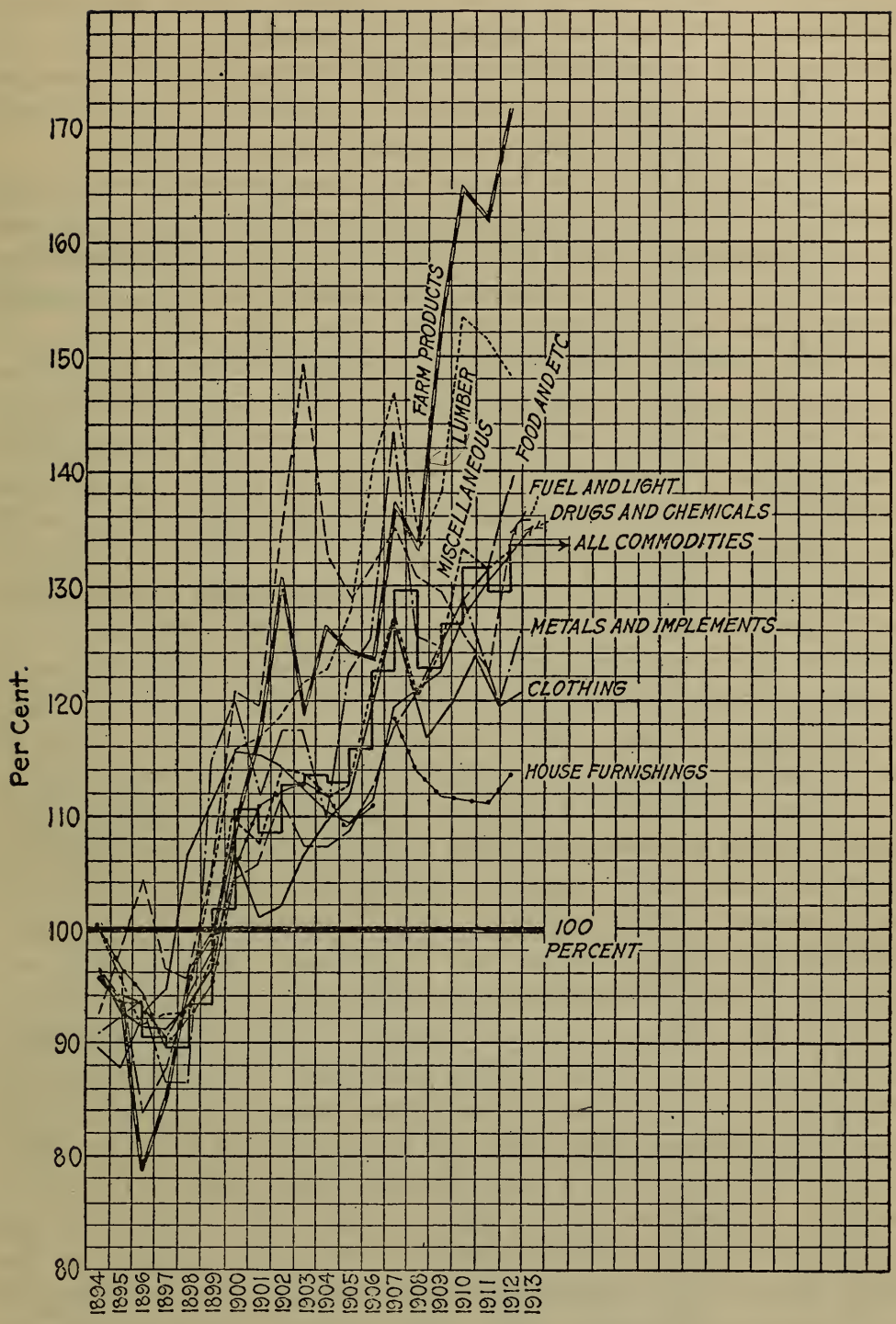


FIG. 6.—RELATIVE PRICES OF COMMODITIES BEFORE THE WAR

The trend of increasing prices was also manifest before 1914, from 1900 to 1913 the increase was 33⅓% whereas from 1913 to 1920 wholesale prices increased 138% and balanced retail commodities 101% while union scale of wages advanced 48%.

subordinate position, being forced to carry out plans and policies worked out often without regard to his knowledge. On the other hand, carrying on business on the competitive basis, many companies were unable to realize the advantages of coöperative service except through forcing the competing companies out of existence.

The solution was thus sought not in engineering, *constructive* methods of pooling the resources and coöperatively rendering service to the community, but in the *destructive* practice of undermining the productive forces of competitive companies in order to gradually reduce them into submission and buy them out. This process of absorbing, merging, controlling, etc., financially weaker competitive companies resulted in securing many excellent physical advantages for these united public utilities, through more flexible systems benefited by greater diversity of load, etc., but the greater the financial advantages secured through this policy, the less important appeared the necessity for improved methods. On the other hand, virtual control of practically all sources of electrical energy in a territory served by one company, made its power dangerous, at least potentially, to the community and the public service commissions were created to compromise the interests of the public and the public utilities whenever they conflict, whether on the question of rates of service, or transportation, etc. Much criticism has been heard regarding official interference on the part of commissions in private enterprises, as well as criticism of the leniency of some commission in favor of public utility interests. Both are inevitable for no compromise could possibly entirely satisfy all concerned. More serious criticism aims at the principle itself but whatever the arguments are, the main weakness of public service commissions was in their indifference to the matters of national economy and technical, managerial methods practiced by public utility companies. It should always be remembered that whatever are the conflicts between the public utility company's interests there is not and there could not be any conflict between the interests of a local community and these of the entire country. From this broader point of view the interests of the people are identical with the interest of the whole industry, as the health, comfort, and prosperity of one depends on the well-being of all, yet narrow, temporary and selfish motives sometimes obscure this truism, while again, individual interests and aims are frequently in a direct contradiction (under our present regime), to the national objectives.

Although nearly all large American cities are served with electricity for light and power from systems well centralized, represent-

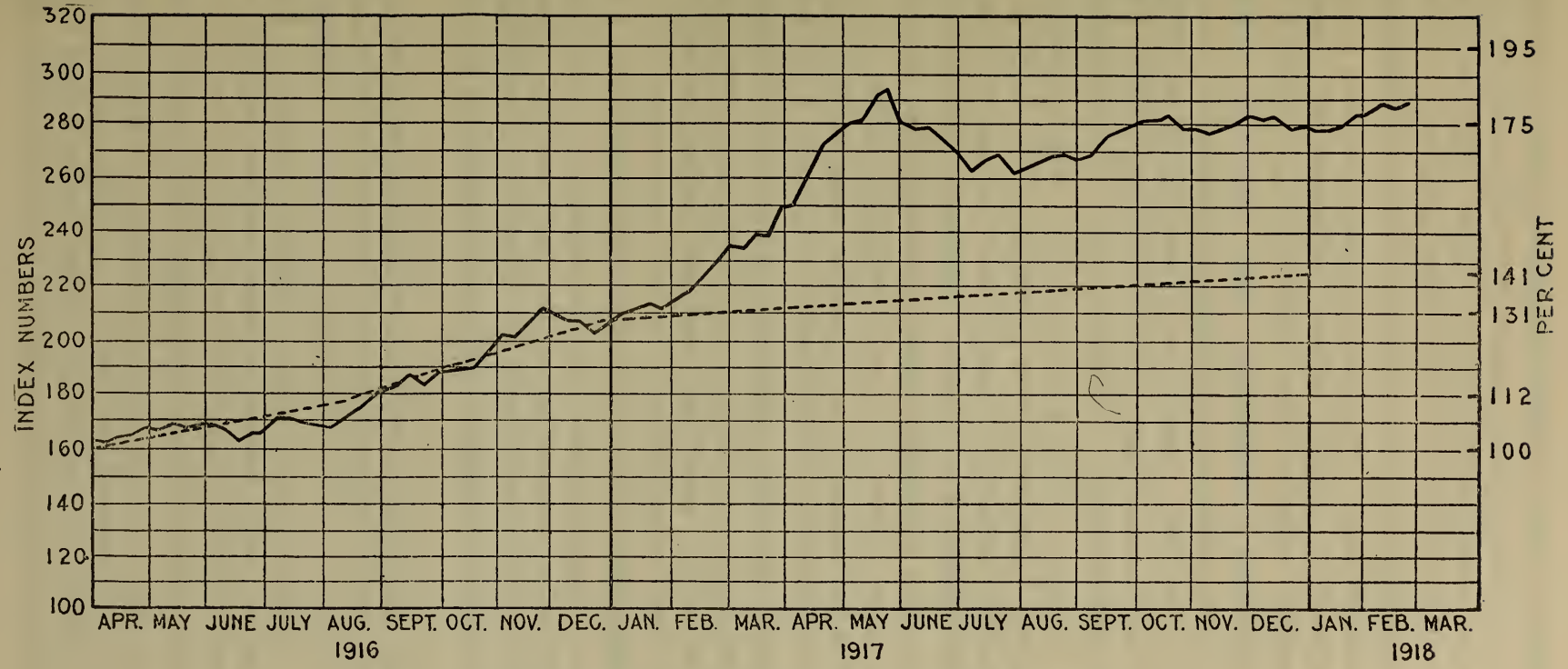


FIG. 6*a*.—RISE OF WAGES LAGS BEHIND THE INCREASED COST OF LIVING

Until our entry into the war wages (dashline) were proportionate to the cost of living. In 1917 increase of wages was retarded while prices of commodities (solid curve) advanced rapidly, thus putting labor at disadvantage and causing demands for higher wages. (Authority: Annalist, 1918.)

ing a comprehensive whole, capable of fairly economical generation and distribution of energy, it is comparatively seldom that traction companies are coöperating in the joint use of their stations and lines. Such a measure is capable of producing many advantages in so far as combined equipment due to the diversity of power, lighting, and transportation peaks could jointly satisfy greater demand without duplicating individual capacity, offering simultaneously thermodynamic advantages of better load distribution and possibility of using larger units and correspondingly lower water rate and fuel consumption. Furthermore, use of substations, feeders, etc., on this basis is capable of reducing the overhead charges on some avoidable duplications. Such a coöperative plan if extended further would include hydro-electric stations, as in the case of the Mississippi River Power Company, selling electrical energy when available to the Union Electric Light and Power Company of St. Louis or of the Philadelphia Hydroelectric Company, the entire output of which is sold to the Philadelphia Rapid Transit Company. Not less important advantages may be secured from the coöperation of central stations with private plants whenever the discontinuation of such isolated plants is inadvisable, by using central station service during the periods or seasons when exhaust steam is not needed for manufacturing processes or heating and relieving the central station peak load during much crowded winter peaks when the isolated plant may use its own electric-generating equipment instead of reducing valves on their steam-supply lines.

Central heating plants in some instances could be similarly participants of such a comprehensive coöperative scheme, all contributing very materially to the conservation of our fuel resources, relieving correspondingly a certain capacity of the railroads and contributing not only to the mutual advantages but to the prosperity of the entire nation.

Carrying this plan farther, many hydroelectric developments that are possible are impracticable on account of industrially undeveloped surrounding territory. With electrification of trunk railroads or their sections undertaken as a part of national program of public work, these projects would become in many instances entirely practicable and would contribute immensely not only to the conservation of fuel resources, but during the construction period would absorb a large number of otherwise unemployed men. Ultimately such electric roads would connect our ports of foreign commerce with interior producers by cheap and efficient routes, conserve fuel, reduce the expense of its transportation, make the use of poor fuels prac-

ticable and with all would facilitate export and develop the industries along the lines. Obviously an undertaking of such magnitude could hardly be carried out by private organization, but the timely practicability of such comprehensive projects strongly suggest itself, especially considering the future reconstruction of railroads, necessity of new rolling stock, extensive impending maintenance and improvement of road-bed, etc., the cost of which is estimated at $6,000,000,000, still leaving locomotives only 5 per cent efficient and tracks working only 1 per cent of time. Electrified railroads show such decided advantages, that Belgium under competent leadership refused to rebuild war-worn railways without electrifying them, while Italy, forced by dearth of coal, is already a pioneer country in this direction, not to mention comprehensive and ambitious Russian projects.

Whether we would adopt new principles or modify the English program for reconstructing power industry or pass a bill designed to provide for the national security by furnishing means for better utilization of the existing sources of electrical and mechanical power and for the development of new sources of power and "for other purposes"; whether we adopt the scheme of super-power stations or continue fragmentary extensions and new constructions "when and as" needed, we must remember that it takes longer to provide the sources of power than to extend the industrial demands for it. It hardly seems reasonable, however, in the light of our past experiences, to expect that private capital may unite on the scale essential for such a nation-wide plan and the public underwriting of utilities [32] may help to solve the problem of its financing. But whatever the form of ownership and control and whatever the extent of power application, *the principles of administrative management and operation will determine the success or failure of the undertaking.*

To satisfy this need of the nation for more and cheaper power in the best possible manner is clearly the paramount task of industrial administration. If the power industry is to be conducted solely for securing the maximum possible profit, many needs might be left unattended as their satisfaction may not be such as to bring direct or attractive enough returns to the privately owned enterprizes. In the case of isolated or factory plants such instances are not thinkable since such a plant is a part of the whole establishment and therefore its very existence depends on the satisfaction of all the demands, the satisfaction of which contributes to the success of the entire organization. This is not the case with a privately owned public utility, tramway, railroad, etc., serving a community, inasmuch

as they may find certain classes of service not sufficiently profitable, yet the harm done by such discrimination to some individuals, groups, activities or even to the progress of the community and the country does not necessarily or immediately hurt public utility owners and in fact such discrimination may be even temporarily profitable.[40]

To obtain for the community the maximum satisfaction and the best service it is essential that the interests of the community and those of the public utility be identical like those of factory power house and the factory itself. So long as they are not, various means are being tried to compromise their conflicting interests. Whether the Public Service Commissions and legislature or municipalization and nationalization of public utilities will solve the problem, is a question which we shall not discuss, but whichever will be the outcome of this issue, one problem must be solved immediately, namely this of efficient administration of the power industry.

A true mastering of power production involves the development of fundamental principles embracing three main groups of the problem:

First: as to what kind and form of power is required; what is the demand; what is the probable growth for each; where are the centers of demand and where are the centers of generation and distribution; and what is the best location and suitable equipment for meeting above requirements.

Second: as to what kind of materials, supplies and other technical requisites can best meet the requirements; what processes are involved and what methods should be adopted

Third: as to conditions under which the men should be engaged —living and sanitary arrangements; mode and extent of compensation; working hours and nature of work; mutual relations, training and advancement, etc.

In other words the whole problem reverts to the application of such principles and methods whereby *the mastering of power production can be carried out for the common good of producers and consumers.*

A system of management is defined by Gantt "as a means of causing men to coöperate with each other for a common end. If this coöperation is maintained by force, the system is in a state of unstable equilibrium, and will go to pieces if the strong hand is removed. Coöperation in which the bond is mutual interest in the success of the work done by intelligent and honest methods produces a state of equilibrium which is stable and needs no outside support." [34]

It is the conviction of the same writer that the industrial relations established "on the basis of democracy will yield as good, or better, results than those now in operation under autocracy." [35]

Autocracy in industry, as was stated in a public speech by a government agent [36] "must fail with the fall of the Hohenzollern dynasty. The same peace which frees the World from the menace of the autocratic militarism—should free it from the menace of autocratic industrialism as well." There can be no doubt that extremely large possibilities exist in the eliminating of the sense of irresponsibility as to the methods and principles upon which the

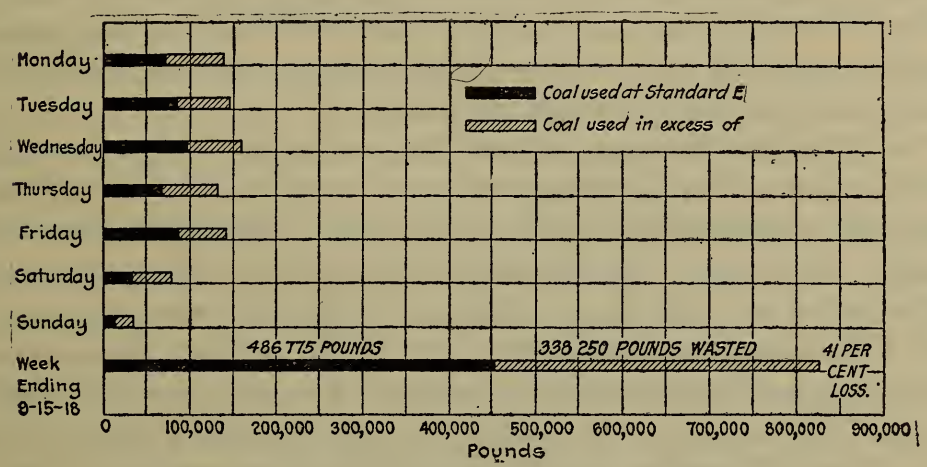


FIG. 7.—COAL WASTE IN AN AVERAGE PLANT; 41%

Average plant under slipshod management, without instruments, training, records and rewards wastes 40% or more of fuel used. (Composite diagram from author's practice.)

production is carried out. *The revenue producing factor is not the investment but the method of its use,*[23] whether this revenue is reckoned in terms of dividends paid to the share-holders or in the added welfare of a community and prosperity of the country.

Success or failure in mastering production determines the future development of society, rise and fall of nations, the form, the order and the ideals of our relations. Upon those who are called to organize, plan, direct, and control production, depends whether incompetency, privilege and autocracy, heretofore supporting such a state of affairs, or efficiency, industry, and coöperation will lead us to a higher form of social order.

Yet even superficial observation shows us how true is the old, and well-known statement that "in the social production which men carry on, they enter into definite relations that are indispensable and *independent of their will;* these relations of production corre-

spond to a definite stage of development of their material powers of production. The sum-total of these relations of production constitutes the economic structure of society—the real foundation, on which rise legal and political superstructure, and spiritual processes of life. No social order ever disappears before all the productive forces, for which there is room in it, have been developed, and new, higher relations never appear before the material conditions of their existence have matured in the womb of the old society."

Heretofore no management that could produce the most goods was needed; in fact it was feared that the condition would arise making it impossible to sell them at a high price; likewise the efficiency of management was a thing much talked about but never seriously practiced as far as national production was concerned, for the economic system was based on waste.

Recently, the Emergency Fleet Corporation was obliged to take away much needed shipbuilding contracts from some firms that had too boldly practiced their "right" to waste time, materials and to mismanage production. Mr. Redfield, Secretary of Commerce, said that we are a wasteful nation. He said it was all a matter of character. He called attention to the fact that 65 per cent of the value of the tree is wasted in making lumber. But Mr. Redfield ought to know that waste was the ground plan of our system; that it was not a matter of character at all except of the character of our business system. It pays best to waste forests, as it pays best to waste coal and food and such other stores of nature. In the greatest of all wars we lost something less than 50 per cent of the number of people which our system found profitable to kill and maim annually in the steel mills, railroads, and elsewhere through industrial accidents. "It is called a good business to take off cream and throw the rest away. From the view point of the investor it would not be good business to turn the engineers and masters of production loose to save and serve the people to the best—even their advice is seldom asked, for *Waste is the System.*" [37]

The grave question now is: shall we carry out our reconstructed industries on the same basis that has been the foundation of our old business system—waste? "It did pay to waste human life and health, for those killed and invalided by industries were replaced by European immigration without expense. It did pay to waste natural resources and materials for the waste of production has been shown as a legitimate part of cost of production and we charged the customers for the coal and commodities thus saved. It did pay to waste time in idle machines and idle capital for we devised a plan

whereby the consumer had to pay for it. In other words the business system succeeded to make profit out of any kind of industrial waste. That is why efficiency in the past could not become a part of business policy," said a speaker during the discussion of H. L. Gantt's paper Efficiency and Democracy at the Annual Meeting of The American Society of Mechanical Engineers in 1918.

Our production was inefficient because we aimed to sell commodities dear; our organizations were unfit for production for we planned to make fortunes by speculation, not by producing commodities; our knowledge was superficial as we did not have to know much to plunder our natural resources. Our speculative boosting up the prices overtaxed the buying capacity of our people, so that in order to maintain business we had to export, but the other nations also had to export and, when there are no more open markets, industrial wars follow. The wars further tax people, reduce home-consumption of goods and increase prices and the people revolt against the *system that makes commodities dear and men cheap.* Such an economic system contradicts itself, it destroys itself from within, it creates excesses and offers no solution. Yet the new adjustment of economic forces can not take place without a new mode of mastering production and so the new principles and methods must be developed and practiced.

We paid dearly for these lessons. Idle men were to be fed, and those who worked hard had to share with non-producers; idle machinery was to be paid for and the reduced output bore extra charges for this, sending the prices upward; wasted coal caused untold misery last winter; wasted material was included in the price of marketable commodities; mismanaged rail-roads have thrown men out of work for ten Garfield days and announced "embargoes." Mismanaged electric companies hampered the production of the most needed goods by shortage of power they were unable to generate, and millions of dollars had to be given to them by the government to put them on their feet.

Even if we did not know what coöperation means and how production could be carried on for the common good, we should have been incredibly stupid not to benefit by these lessons. So we took under Governmental control, railroads, shipping, express companies, telegraph, shipyards, aircraft production, distribution of food, steel and some other commodities, but *we did not get the coöperation.* What we got, proved to be vastly better than an individualistic, anarchic scramble for individual gains and muddling with things. But coöperation was simply sidetracked and substituted by co-

ördination. And this means regulation from a central office without any assurance that the orders are not arbitrary. *Coördination* is a man-made law; *coöperation* is based on the laws of nature. One is decided by debating mere opinions while the other is based on facts. One is the way of lawyers and politicians—the other the method of engineers. You may debate and take votes on prohibition, but you can not order alcohol to become non-intoxicating.

The shortcoming of any enforced coördination is that it may be arbitrary. As such it may or may not be for the common good, indeed it might be used to develop new forces of oppression and exploitation. Democracy proved itself superior to Autocracy; coöperation has to prove its superiority over coördination.

The manager, management engineer or whatever name may be used has to formulate *the policy of mastering the production, consistent with the fundamental principles or natural laws* of social development, as opposed to mere conformity with his personal view or fancy as to "righteousness," "legality," "tradition" or what not. As the word itself indicates, the *management's function is coördination of man's efforts* and as such it involves *conservation of men's efforts* by

1 Best procurable living conditions
2 Highest degree of hygiene
3 Broadest education
4 Vocational fitting
5 Study of science involved in industrial process
6 Acquiring skill in operations
7 Fixing the useful habits
8 Making work fascinating
9 Minimizing dangerous and manual labor
10 Increasing production per time unit
11 Minimizing working hours
12 Providing for productive relaxation.

When these elemental requirements are complied with, the complex requisite of industrial economics—this of *maximum production with minimum effort* is fulfilled.

This requisite of paramount importance opens a new field for engineers. "War conditions have not only hastened public recognition of the engineer as an expert in applied science and fostered solidarity of the profession, they have also opened to him new fields of activity," says an eminent investigator. "Back in

1914 most people believed that the war could not last long because enough money could not be found to finance it. But three years of experience have made it clear to everyone that although money is plentiful, it is usless if there is nothing to buy; so that winning the war depends on increasing production by an amount which has been estimated as the output of at least ten million additional industrial workers. This extra production may be secured either by training more workers or by increasing the output per worker by engineering methods. Hence, there has arisen a pressing demand for men who can deal with labor and with business administration in the engineering spirit. This

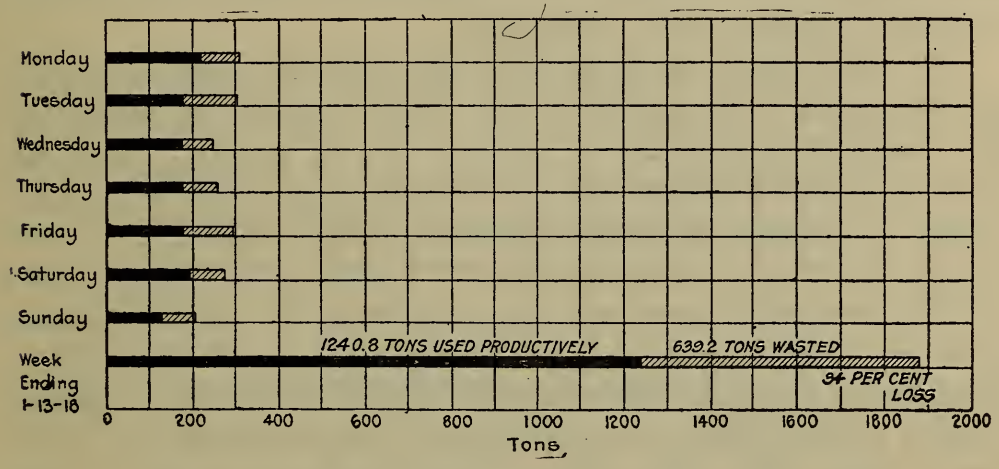


FIG. 8.—COAL WASTE IN A MORE CAREFUL PLANT; 34%

About one third of coal is lost in power plants receiving ordinary managerial attention as to upkeep and having a few instruments casually installed. Some 10% of coal could be saved by such superficial means.

demand is further emphasized by the fact discovered by the Federal Trade Commission, that only 10 per cent of the manufacturers in the United States know their actual cost of production. The determination of these costs requires a scientific study of production which only an engineer can make. This work involves the analysis and apportionment of overhead expenses, and thus leads at once to such fundamental questions of economic justice as: Should the capital invested in idle machinery be paid wages, though idle workingmen are not?

These new opportunities for the engineer have been gradually developing for a number of years, but the profession as a whole has been slow to discern them. The war has focused attention on them and precipitated a general recognition of them. It is also evident that the mastery of these new activities depends in

greater measure than does the mastery of the traditional types of engineering on the personality of the man." [38] Add to the above requests put up to industrial administrator or manager the definition made by an English unionist that "the works manager is out for fullness of life, just as much as is the poet" [39] and his task is fairly complete with one important modification: that by fulfilling all this he infringes no human right.[40]

The control of resources, of means of production, or even of political power is of no avail whatsoever unless the productive forces are so directed and organized that the new industrial relations shall better serve large masses of people. It is the knowledge and the ability to do things that assumes the natural, intrinsic authority and leadership.

It is inevitable, therefore, that the industrial administrators, pre-eminently the engineers—are alone capable of mastering the complex mechanism of modern life in motion. The old masters of static things have no function in the modern dynamic society. The new leadership cannot be either autocratic or arbitrary, for dealing with the laws of nature, with intrinsic laws of life, not with man-made laws of barristers, it can neither alter nor misinterpret them. Where errors spell annihilation, there is no room for theories and opinions, whims or desires. Action must be taken on the basis of the knowledge of facts; hence those who know what to do and how to do it must assume the leadership; their authority, being based upon the knowledge of facts, can not be questioned, disputed or denied any more than the facts themselves. This authority is not conferred on them by vote nor is it taken by force—it is theirs so long as it serves humanity in its quest for life and happiness.

In the coming order of things the success of industry will depend on a maximum of production with a minimum of effort; improvements will be measured by hours saved from toil for enjoyment of life. Stability of industry will be reckoned in the stability of occupation and will depend upon the quality of the product. Quality is wanted but will be measured in terms of longer service of goods in relation to the time required for their production. Wages should adequately provide for the fullest known measure of healthy, happy life and reproduction. No undertaking will be tolerated unless it be safe, healthy and pleasant. For dangerous service only volunteers will be accepted. Output will be determined by actual existing need for the product by all people, not by their purchasing capacity. Idleness will be

brought into disrepute for it breeds parasites, for it imposes on society extra burden whether it be idle land, idle men, idle machinery, idle buildings, capital, or idle knowledge and talents. Industrial relations will be based on fullest coöperation. This plan can not work under arbitrary, incapable leadership—it presumes that it is definitely known in every instance what to do and how to do it.

In the course of the following chapters on the mastering of power production we will try to show, by the examples of one particular branch of production, even though the manufacture of power is and always was pre-eminently the domain of engineers, how considerable is the waste caused by incoördi-

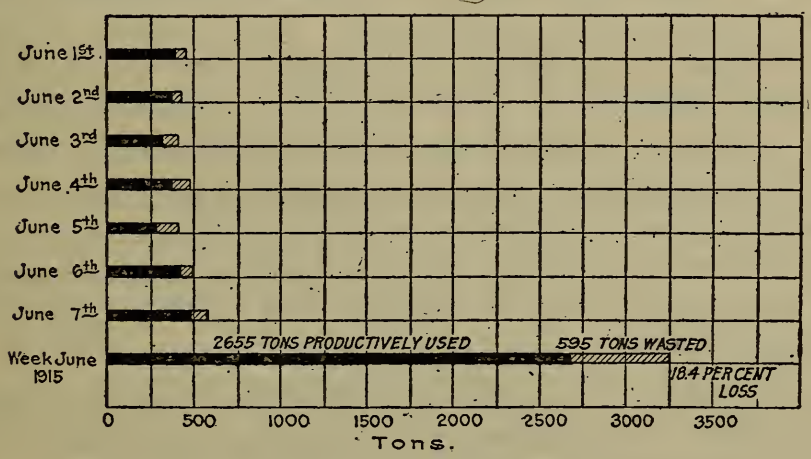


FIG. 9.—COAL WASTE IN A SYSTEMATIZED PLANT; 18.4%

In plants well "systematized," equipped with necessary instruments, keeping records and caring for ordinary maintenance losses are below 20%. This waste is due to lack of scientific studies and training and chiefly to the force disinterested in results of their work.

nated, arbitrary ruling of managerial problems. We restricted the scope of discourse within the walls of power stations, formulating and illustrating sound principles of management guided by studies of facts and animated by a desire to apply the knowledge for the benefit of all, not of few. Difference of opinions has no room where facts are established and experimentally proven. Similarly no conflict of interests may be expected wherever the welfare of all is supreme; hence the fullest coöperation may be expected only in establishments conducted on the basis of full knowledge of facts by all concerned.

Any system of management upon final analysis appears to be merely a mechanism. As of such, good use or poor use may

be made; as any tool it may be applied to a right or wrong purpose and so long as "scientific management" or any other form of management is applied as a panacea for boosting the dividends, it not only falls short of accomplishing its social function, but to the contrary, creates friction and further antagonizes interests of benefited and benefactors; yet no definite aim can be achieved without proper mechanism and the scientific method of controlling the production seems to be particularly and admirably fitting for the aims of social mutuality of the coming industrial democracy. What we mean here as a mechanism is, of course, not an agglomeration of "short cuts," stunts and universal remedies for this and that industrial ill and waste, but an organically whole philosophy of industrial coöperation for production carried for the common good. Real mastery of production presupposes a profound knowledge of science involved and technical experience, but it cannot be practiced successfully in an arbitrary, dogmatic fashion. No authority of those directing the production is capable of justifying the issuance of an instruction calling for dilution of acid by adding water, yet in dealing with human relations, orders sometimes unhesitatingly are issued and enforced that are fraught with equally dangerous consequences.

The conservation of fuel cannot be brought about by orders and appeals, nor by compulsory or voluntary installations of fuel saving devices and improved machinery. Desire to save fuel on the part of those who actually use it is insufficient unless supported by a knowledge superior to the one prevailing. Special care, attention and extra efforts are capable of producing little unless means are provided to watch the results, yet monthly compilation of statistics in a centralized bureau seldom shows "why" the loss occurred to those who cause the waste whether through ignorance, fatigue, or managerial handicaps. Moreover, long working hours, low wages, employ of untrained men, low intelligence, etc., must be done away with before the fuel conservation may be seriously attempted. Similarly all the coal saving devices and appliances may improve results only if properly used, while if neglected, misused or abused, they cause a direct harm by wasting labor and material for the manufacture of those devices which are not properly used. Automatic equipment and apparatus are in fact frequently worse than none, since dependence on their work and regulation promotes a sense of security and care-free spirit with a common consequence of addi-

tional losses "coming and going" with each variation of furnace and load conditions, while, again, an endless number of examples proves the superiority of an intelligent manual regulation. All this, of course, applies only to the average cases and does not imply the abnegation of intrinsic values of such devices and improvements, which simply fail to serve the incompetent users. National campaign for fuel conservation will fall short of desirable results unless every individual plant earnestly and untiringly studies its problems and seeks and follows competent advice of those specializing in the art and science of mastering power production.

Let every plant owner or manager frankly answer to himself the following questions and then act accordingly:

1 How many pounds of steam or kilowatt hours are actually produced with one pound of coal on the annual or monthly average?

2 How many pounds of steam or kilowatt hours one pound of fuel is *capable* of producing in the existing equipment?

3 To what is this shortage due?

4 What this loss amounts to per year? (In dollars to the plant and in tons to the country)

5 Do the employees know how better to utilize fuel?

6 Are they willing to learn?

7 Who can show them and help them?

8 Is all the generating equipment productively used?

9 Is all the power generated productively used?

10 May purchase or sale of power improve fuel economy?

Such a questionnaire may be elaborated extensively but in a predominating majority of cases no answer to the first question is to be had, and whenever this is the case, the efficiency of boiler operation generally is in the neighborhood of 50 per cent and the fuel losses are usually over 20 per cent.

The Connecticut Committee on Fuel Conservation did not hesitate to state that "it practically amounts to treason to waste coal," yet, without coöperation between plant management and fuel and power experts no better results may be expected than from an army where every soldier feels at liberty

to carry or not the plans of the general staff. Unbiased and competent investigators, after due tests and studies, can correctly determine for each plant under observation what amount of coal is reasonable allotment and the principle suggested to the United States Fuel Administration at the annual meeting of The American Society of Mechanical Engineers [41] in 1917 was to abolish the privilege to waste fuel in inefficiently conducted plants by giving priority in coal deliveries to those who prove that they do use it efficiently. This principle took a definite form of rating plants into five classes so that the needlessly wasteful ones should be the last to draw upon the available supply of fuel. Now, suppose that the most extravagantly wasteful plant furnishes power for the most needed public purpose, transportation or manufacture of important commodity. To leave it without fuel supply may amount to a calamity; leave it alone because of importance of its function means to protect waste, incompetency or what not. The autocratic way would be to choose between the two and thus cause public loss to the country one way or another; as opposed to this, a truly democratic way is to offer coöperation, "call for a doctor," and by a careful study of causes establish the procedure for elimination of losses. Study of causes of inefficiency discloses a more economical way to manage the plant and the plant should have the benefit of such disclosure. If the management is unwilling or unable to do better, it is not a remedy to close the plant and thus reduce the productive capacity of the country. Selection of more competent management is in such extreme cases a solution capable of satisfying both fuel conservation and unhampered production.

Chapter II

THE LOCATION OF PLANTS

THE effect of a plant's location on the value of the service it renders to the community as well as on economic development and industrial expansion of the neighborhood is a question which, though attracting some attention in the past, has never been adequately met by a comprehensive large-scale development. Individual surveys and examinations were of course made in every case of building a new plant, the thoroughness, accuracy and impartiality of which varied in every instance, but these new developments or new constructions were made with a view of taking advantage of the existing field of activity or reasonably certain prospects rather than of giving an opportunity to the locality to develop and progress. Furthermore, where a need for a new or larger plant exists it is common to find that a territory offering such opportunity for a private enterprise is divided and served by a number of independent, sometimes competing companies which spend more energy, time and money in competing with each other than in rendering service. The inevitable consequence of this is that the community does not get as good or as economical a service as it might if all the efforts and expenditures wasted on competition were wisely directed for coöperation. Eventual unifications of a number of small competing companies inherit besides the indebtedness of the previous period a number of small, scattered plants, substations, etc., which are quite below in their efficiency of what might have been possible if a large unit central station were erected originally in their stead. The community that cherished an idea of benefit derived from competition of divided interests is finally bearing the brunt of accumulated burdens both financial and those resulting from engineering disadvantages and pays the penalty for permitting duplication of efforts, low efficiency, and narrow vision.

Upon the analysis of many such situations both in this country and abroad, the problem of location and the size of the plant appears in all its importance, as far as public interests are concerned. It may be best reviewed if its effects are considered separately as those affecting the *service* and those influencing the *conservation.*

Service Requirement Upon Location

The most commonly recognized rule regarding the location of a central station is that it must be situated as near as possible to the center of distribution. Such location permits the shortest lines from the generating stations to the periphery of the territory served with attending minimum drop of voltage and line disturbances. While this is particularly true with direct-current service, it is also correct, though not equally important, in cases of alternating current, as it may be comparatively economically transmitted over almost any distance chiefly because of the simplicity with which the voltage may be stepped up or down. The beneficial result of locating the generating station at the center of distributing system is quite evident, though among other things we may note: smaller liability of interruptions on shorter lines; any accident affecting fewer customers than it would if on a longer transmission line; a steadier voltage, which for some industries is a very important factor, etc.

The aim of the centrally located generating plant must nevertheless be carefully studied in the light of other considerations such as: probable direction of growth of electrical demands; convenience of obtaining and maintaining the right of way and distributing lines; possibility of future enlargements; possibility of tying with other generating plants in the vicinity and, of course, economy of operation and other considerations discussed later. Again, while under some conditions the private ownership may find unsurmountable difficulties preventing the locating of the plant in a most advantageous place—such as unbuyable real estate, legal obstacles, too large an initial money outlay with remote date of earning dividends, etc.,—with public undertaking of such development these handicaps may easily be overcome and outweighed by ultimate advantages to the community or even to the nation.

On the other hand, the nature of the requirements for one kind of current or another must be taken into serious consideration in determining both the kind of current and location of the generating plant in relation to the distributing system, which may be well exemplified in case of electric traction. Furthermore, the industrial communities not infrequently offer good opportunities for locating a generating plant in that vicinity while residential communities may strongly object to a power plant in the neighborhood. The British Reconstruction Committee concludes in this connection that "the health of the great industrial centers and the congestion of the railway lines in their neighborhood would be radically improved by

arranging for the conversion of coal into motive power to be carried out away from the densely populated centers." (20-2)[81]

Thus a few outstanding considerations regarding the proper location of a generating plant from the viewpoint of service are:

a Minimizing line troubles and interruptions through radial distribution from a centrally located plant instead of diagonal branching off lines from the plant near the edge of the area served

b Reduction of disturbances and interruptions of service by locating the generating plant so that minimum number of substations will be required

c Avoiding as far as possible periodic or temporary drop of line voltage necessitating costly regulation or causing damage to manufactures served

d Possibility of interconnection of plant with other plants or preferably hydroëlectric stations

e Possibility of enlargements or extensions as the service may require

f Assurance of uninterrupted delivery of fuel, water and other materials and supplies insuring uninterrupted generation

g Attractive living neighborhood or convenient communications for employees preventing disturbances on account of difficulties of securing operatives and minimizing tendency to high labor turnover

h Ground suitable for stable foundations further assuring uninterrupted operation.

While the above conditions are essential for the selection of a site suitable for a plant from the standpoint of reliable service, a number of other requirements are no less important but they are so closely linked with these necessary for economical operation that they belong to the next group of consideration.

Conservation Requirements Upon Location

Steady reduction of the cost of electricity to the consumer up to the time of the World War was made possible chiefly by inventors, designers, and builders of equipment, in spite of the muddling with the methods of its use. Three factors deserve mention in this connection.

First, direct current with its limited sphere of distribution was replaced by high-voltage alternating current which made possible the generation of power in large central stations with corresponding commercial advantages of mass-production with comparatively insignificant transmission losses. Second, as a direct consequence the advantages of large central stations stimulated the design and construction of large size turbo-alternators of high thermal efficiency, made profitable installations of large boiler units, double-end furnaces, and similar developments. Still further advantages were secured from the wide range of characteristics of the connected load with its diversity factor, off-peak load, etc. This made possible to serve a cumulative connected load far in excess of the plant's own capacity. Lastly, mass-production of steam with corresponding great amount of coal and ashes to be handled promoted the development and adoption of automatic stokers, coal and ashes handling machinery and use of measuring and controlling instruments. This semi-automatic, centralized mass-production besides evident advantages in marketing the product, permitted, even made it imperative, to employ highly specialized operators in place of cheap but inefficient laborers.

This evolution tends toward the discontinuation of small sized, scattered, inefficient plants and substitution by large central stations or even so-called super-stations. This obviously does not include those factory plants, industrial and institutional power plants where electricity or mechanical power is merely a by-product of steam which is used in manufacturing processes, for heating, boiling, cleaning, etc., as the most economical central station service can not begin to compete either in fuel economy or in cost with steam-electric generator acting primarily as a reducing valve and only incidentally delivering the current. Moreover, of all the physical conditions permanently affecting the economy, the location of a plant is a most serious one since it is practically unalterable. The most influential of these local conditions are those in relation to

a Fuel
b Water (for boilers and condensers)
c Labor
d Transportation
e Neighborhood
f Population
g Legislature

Inasmuch as *fuel* is the most important factor both in expense and in the efficiency of any steam or other thermal power plant it is

evident that—(1) sufficient supply of fuel and (2) minimum haulage or transportation are the conditions of greatest importance and while it is desirable it was not always practical to locate plants at the mouth of the coal mine or in the middle of the oil field, those plants that pay less for fuel transportation have economic advantage, as well as being more desirable from the national view point of conservation of efforts. Closely related to this point is the adaptability of the furnaces for the local fuel supply, while in locations distant from any coal field the advantages are on the side of one which can use fuel delivered by waterways or, if the coal is to be conveyed by rail, it is more desirable to bring the coal lowest in ash and moisture in order to reduce the transportation of refuse. Furthermore, the location of the plant at the navigable water front or on the railroad offers more advantages than the one requiring extra hauling or even carting of fuel. This fact is so obvious that it is often forgotten when intricate considerations of a few extra miles of transmission lines or economic advantage of certain real estate complicate the issue.

As the result of the location of a plant relative to the price of fuel the type and character of the auxiliaries and even main units that would be advantageous in one locality may become extravagant luxuries in another. For instance: thermodynamic advantages of electrically driven auxiliaries, economizers, etc., with the cheap coal used may not save enough in fuel to cover the excess of fixed charges.

Water supply follows closely in its importance upon the fuel in affecting the operating cost and safety of the plant. Water supply bears upon:

1 Water power available
2 Abundance at all seasons for boiler feed
3 Scale forming qualities
4 Sufficiency and suitable temperature for condensation
5 Drinking qualities
6 Electrolytic action
7 For by-product extraction and electro-chemical processes, etc.

It is altogether desirable to provide every thermal power plant with at least a small source of water power. The advantages of such combinations are large and important considering the expenses for banking extra boilers, carrying peak loads, maintaining reduced service during accidents and disturbances, etc. Ample supply of water for boiler feed is of course imperative and plants depending merely on the city water supply are at times in a precarious condi-

tion (especially in small communities) not mentioning usual high rate of water purchased. Again, the quality of the feedwater determines the desirability and advantages of sometimes large investments in water purification or softening plants with their permanent operating and maintenance expenses. Moreover, the character of the feedwater affects very largely the life of the boilers and boiler tubes besides necessitating extra investment for spare boilers needed during frequent cleaning outs and expenses connected with the removal of scale, change of gaskets, etc.

Water for condensing sometimes determines the entire specification for generating equipment. While non-condensing engines and turbines are less economical in operation than condensing, certain factory power plants could gain nothing from the use of more expensive condensing installations. The quality of the water for condensation again often severely affects the cost of maintenance on pumps and condenser tubes, while the lack of water or its high temperature sometimes warrants heavy additional investments in cooling ponds, towers, sprays, etc.

While the two above physical conditions of the locality in which the plant is situated materially affect both the character of the equipment best suited, the operating cost and the fixed charges, the *labor market and the living conditions* in the locality have perhaps a still more direct influence on the managerial problems. Too little attention has been commonly paid to this vital question. Away from industrial centers both skilled and common labor is not readily obtainable, and living conditions for men are sometimes unattractive. Economical disadvantages of shifting personnel are more pronounced in power plant work than in any other industry since a new-comer has more to learn about local peculiarities of plant, equipment, mode of operation, etc., than any skilled mechanic in any industry when he changes his place of employment.

The managerial problems under such condition become more exacting—all operations should be clearly and definitely standardized, written in plain language, instructions prepared and personal training provided in a systematic way. It is not so much the problem of hiring fit men as it is to make the men hired fit the job and the magnitude of such a task can be appreciated only by those who have had the opportunity to actually solve it.

As a remedy for the disadvantages of local living conditions, the building of a colony for the employees at a considerable investment should sometimes be resorted to and under still other circumstances the employment of reserve men or understudies helps to solve the

problem. While these men regularly have little to do but learn and keep themselves in readiness in cases of sudden sickness or absence or resignation of the employee, especially one holding a licensed or skilled responsible position, the ready, available substitute is invaluable.

Again, the school for the employees' children, shopping facilities and prevailing prices of produce, rent, recreation facilities, in short, everything that determines the cost of living, standard of the community, etc., should be taken into account as it in turn is reflected in the rate of wages and stability of employment. Furthermore, social environment, churches, clubs, class of neighborhood, climatic peculiarities, etc., sometimes make otherwise desirable positions hard to fill. As the result of operating efficiency and economy hinges on the personnel, in the last count, the influence of local conditions on the possibility of securing and retaining high class, efficient operating men shall not be underestimated.

Transportation facilities, both passenger and freight are closely linked wtih the above discussed local factors. The need for a satisfactory means of receiving an adequate and uninterrupted supply of fuel and other materials is readily recognized, especially where considerable fuel storage is not practicable or even possible. More than one route for deliveries always puts the plant into a more secure position particularly if one is liable to be crippled during a certain season of the year. No less importance should be attached to the passenger traffic, in fact it is more important if the employees are living at some distance from the plant. Well arranged schedules of trains and trolley service and cheap fare or special commutation tickets play an important part in the security and economy of the plant operation.

Lastly, the local conditions, habits and social environments determine the working hours, length of shifts, rotation of watches, etc. While in general most economical operation can be maintained with four six-hour shifts in twenty-four hours, the interplay of various local conditions makes it extremely difficult to put these into practice. Similarly local conditions at times may influence the mode of compensation, being either favorable or hostile to bonus payment, making it necessary to pay at certain days, more or less often, in order to offer the employee the advantages of late evening shopping or to meet the terms of local storekeepers' credit settlements, etc.

The more or less thickly populated *neighborhood* and its character exercises a great influence on the character of equipment and mode of operation of a central station. It has a still more pronounced

effect on the method and equipment used in the transmission of current. Closely related to this is the direction and the rate of the growth of the community served. High-tension transmission, net of substations, underground or overhead lines and allied matters do not directly relate to our subject, yet indirectly, through factors such as power factor, extent and time of peak loads, diversity factor, greater or lesser importance or voltage regulation, etc., are the local factors of utmost importance for successful mastering of power production.

Legislative regulations as a rule are very unlike in different, sometimes neighboring, states and frequently offer serious problems in management. While one plant can not employ any but licensed firemen, the one within a stone's throw is safely operated by men without a tag but with real knowledge. The endless variety of regulations devised by lawmakers for reasons which sometimes are obscure to themselves and seldom beneficial to the community, shall be omitted from this discussion until the engineering profession gains the standing belonging to them as creators and masters.

This brief outline of the few most conspicuous local factors should be sufficient to prove that *neither methods nor economic results may be alike in two plants subject to the influences of different surroundings.*

Centralization of Plants

From the preceding review of the influence of the location of a plant on the character of service and economy of operation a conclusion may be drawn that every suitable locality should be utilized to the fullest extent. Now the question to answer is what might be the advantages derived and accruing from centralization of electric generating facilities, serving economically a large territory and how large this territory might be or how far centralization should be carried.

It has been generally accepted that the concentration of generating equipment offers the following advantages:

1 It is possible to distribute the power economically

2 Because of diversified nature of the load it is possible to operate the system with a better load factor

3 Purchasing supplies and spare parts at a central point has a decided economic advantage

4 The centralization of management and operating force reduces the expenses

5 It is possible to serve certain classes of customers whom the small individual plant could not afford to serve

6 The lower cost of production due to centralized service, makes it possible to offer lower rates

7 Consolidation of interests makes possible the financing of improvements, substitution of new for obsolete apparatus and the extension of service into new territory, and

8 Better regulation and better protection can be provided.[42]

All the above advantages are seen from the viewpoint of an investor —even the lowering of rates as a result of lower cost of generation in a centralized plant is mentioned merely as a "possibility." A decidedly broader and deeper insight into the question is manifest from the stand taken by the British Committee. For them, the economic advantages do not mean higher dividend on the company's stock but conservation of natural resources, human energies, and development of industries in the country as well. The recommendations therefore embrace the following aims:

"Centers, or sites, suitable for electric generating purposes should at once be chosen on important waterways as the future main centers of supply for each of the districts into which the country is to be divided. (48-2) The sites so chosen should be as large as possible, having in view the land available in suitable localities, and should have ample water and transport facilities. Land is required not only for the power stations themselves—which for the sake of security and safety would have to be suitably subdivided, that is, they would not be contained all in one building—but for the processes involved in the extraction of by-products from the coal before it is used for the production of power, where such extraction is found to be justified. It is also required for the development of electrochemical processes, which may be most conveniently carried on in close proximity to the power plant. This condition entails the sites being chosen outside, not inside, the towns. The health of the great industrial centers and the congestion of the railway lines in their neighborhood would be radically improved by arranging that the conversion of coal into motive power was carried out away from densely populated centers.

"Plans should be prepared for the construction immediately after the war on these sites of the first installment of large superpower plants capable, first, of supplying through a comprehensive

electric power distribution system which must also be arranged for the existing demands of the community; and, secondly, of supplying electrical energy at the *lowest possible price* for new processes and manufactures" (48-4).

If power is to be supplied throughout the country at the *lowest possible price,* the following conditions must be secured:

1 The power users in each industrial district must be supplied from one common inter-connected electrical power distribution system

2 Large generating machines, not less than 20,000 horsepower, must be used and they must be erected in the best possible position for economical production. In the more important industrial districts generating machines of 50,000 horsepower might be advantageously used

3 Power available from surplus gas or waste heat should be turned into electrical energy on the spot in local plants which would feed into the main distribution system. As regards waste coal—coal which it does not at present pay to bring to the surface—this could, where transport was the ruling consideration, also be used on the spot.[18]

In all these considerations it is important to note that the emphasis is put on the aim of supplying the energy at the *lowest possible price* —not merely production at the *lowest possible cost,* for the advantages of centralization from the viewpoint of the national economics as emphasized in British Report, is not a boon, but a danger if it gives a special privilege to one group of investors. Such privilege, when practiced, accumulates wealth in the hands of one group at the expense of not only the development of production and of the country's industrial progress but it also reduces the purchasing capacity of the Nation since the wages remain low whenever motive power is not extensively applied on account of its high price.

On the contrary, when the lowest possible cost of production is not an aim in itself, but is regarded as a means for the reduction of price, the accruing benefits are large not only to the community, but to the producers of power as well. The perfection of plant and methods, permitting the service at a low rate by stimulating the power uses in the established field and by opening new fields of application, does increase the bulk of the net revenue even if it is at a lower rate of profit. Furthermore only very large central stations or even systems of interconnected large plants can secure the maximum advantage of best diversity of demands. From this angle

the limit is not how big the system may be but how small it dare to be before unnecessary duplication of installation, efforts and wastes will cause harm to the country. Residential, commercial, industrial, and municipal service must be combined as much as possible with traction and railway load and electrochemical processes, charging secondary or storage batteries, etc. Such widest combination of loads feasible only with a large installation necessarily produces not only the best fuel economy because of the use of large, thermally efficient units but more specifically because it eliminates idleness, losses for banking boilers, and losses due to fluctuating load when the units are not operated continually at the lowest point of their water rate curve or during high peaks for which a considerable generating capacity must be kept idle most of the time. How serious this last item alone is to-day may be seen from a statement of an official of the Interborough Rapid Transit Company who in a discussion of a paper on Modern Central Station Design said: "50 per cent of the machinery in a lighting plant operates only 300 hours per annum, so that it becomes most important to keep down the first cost, for assuming that a plant cost $125 per kilowatt capacity then the interest and depreciation charges upon the portion of it used for the peak load would amount to 5.2 cents per kilowatt hour, or probably five times as much as the operating cost." [43] While it is true that a great many individuals in an organized society are having definite hours to work together, to travel together, to rest together, to go to theaters, etc., no individual can do several things at the same time and the required maximum demand on electric power for each can not coincide. Therefore, the economy of a combination of all requirements in a community for power, light, traction, heating, etc., is fundamental and large-scale centralization and interconnection of plants offers the best service with minimum expenditure of efforts, fuel and time.

Among the additional advantages to be secured from the erection of plants on roomy and efficient sites, apart from those resulting from the increase in the size of the plant the foremost place belongs to the opportunity that a central plant offers for better supervision, as well as development and application of the best operating and managerial methods; next comes the opportunity of offering to the employees more comfortable, congenial, hygienic and safe surroundings and all around better conditions for work; lastly a centralized plant, *if properly managed* is capable of producing higher efficiency and better fuel economy, not to mention the advantages reflecting on the manufacturers and dealers in power plant supplies

and accessories, whose selling expenses may be reduced to a minimum, being unnecessary wherever the purchasing organization of central plants looks itself for sources of supply instead of an army of salesmen searching for new and unknown small buyers of a questionable credit standing.

Isolated Plants

Apart from what has been said regarding advantages of central plants favorably located as regards to fuel, water, distribution, etc., stands the question of block-stations, mill or factory power plants, hotel and institutional plants and the like. While it is almost beyond the need of proof that small electrical plants, imperfectly equipped, poorly located, handicapped by the character of load and unfavorable diversity factor and frequently managed in an antiquated manner, should pass and actually do disappear, this can not be affirmed of all without displaying one's ignorance regarding a large number of so-called isolated plants. Their existence is justified in very many cases where steam as such is a principal item of output. Notwithstanding the fact that electrical energy may be conveniently transformed to meet any industrial demand such as for pneumatic power, hydraulic power, refrigeration, and even heating it is hardly justified in many instances to heat hotels or apartment houses electrically or boil the cloth in a bleachery by purchased current. Again, an endless number of cases may be cited where replacement of existing equipment in order to adopt the use of electricity would increase financial burden beyond the gains of such a change. Similarly, it is entirely feasible to propel ferry boats and ships by electricity generated in central stations on shore instead of in isolated boat-plants, yet the development in this direction has been so far extremely slow.

We shall return to the relations of central stations and the isolated plants in the Chapters X and XI on Analysis of Expenses, and Energy as a Commodity, while here, considering the influence of isolated location of a plant on its operatnig economy only a few characteristic requirements need to be mentioned.

1 Factory power plant should preferably be located on the spot nearest to the steam consuming department as losses in piping are the greatest of all other transmission losses

2 It should be directly accessible from outside both for delivery of fuel and removal of refuse

3 It must occupy the part of ground not needed for the extension of manufacturing departments

4 Provisions should be made for ample fuel storage close to the boiler house

5 To provide for possible future enlargement of the plant careful location of buildings on the site chosen is essential

6 Boiler houses must be located, whenever possible, jointly with engine rooms, as the function of these should be compared with pressure reducing valves. (Nearly 90 per cent of heat remains in steam after it performs the work in an engine in an average case.)

Unfortunately, the effect of a poorly located factory-plant is seldom recognized by the builders who are naturally planning to accommodate the manufacturing processes before any of the auxiliary departments; likewise the architects laying out apartment houses, hotels, institutions, etc., seek first to utilize the space in a manner bringing most rent, and the common result is that the plants are put in places unsuitable for anything else, offering consequently numerous disadvantages for convenient arrangement of equipment, increasing cost of handling fuel and materials, making work for the employee unpleasant and unnecessarily hard. All these taken together tend to increase the operating cost while in many instances, if these unavoidable expenses caused by poor location of a plant are compared with the gains in the renting of manufacturing space made available by cramping the plant in the wrong place, the case proves to be penny-wise and pound foolish.

Examples of Plant Sites

The study of two fairly good examples of solution of local problems by electric companies in the past may further elucidate some of the points brought in the foregoing review. The Philadelphia District [44] offers a few interesting instances inasmuch as the growth of requirements overtook the growth of the electric companies. Local companies having practically monopolized the catering of electricity in the district, coöperate to a large extent with each other in handling various loads; comprise industrial, commercial, municipal and transportation service, coöperate with small hydroelectric development in the neighborhood and met with an obstacle to extending the area of service notably through legal and political limitations.

The existing sources of electric power available for public use within that district were:

Summer, 1918	Kilowatts Approximate Capacities in
Philadelphia Electric Company (total available)	184,155
Delaware County Electric Company (total available	178,638
Philadelphia Rapid Transit Company	76,000
Philadelphia Railways Company	625
Philadelphia & Western Railways Company	4,000
Frankford, Tacony & Holmesburg Street Railway Company	800
Fairmount Park Transportation Company	1,800
Trenton, Philadelphia & Bristol Street Railway Company	800
Eastern Pennsylvania Gas & Electric Company	200
Philadelphia Hydroelectric Company	1,400
Total installed generating capacity in all companies	269,780
Total actually available power	261,200

This capacity is divided among over twenty power plants scattered in an area bounded by the Pennsylvania-Delaware state line, the Delaware River, and the southern end of New Jersey, as shown by Figure 10. This area in its three main districts has diversified requirements depending on the nature of the industrial or residential development thus:

	Northern	Central	Southern
Industrial	65 per cent	37 per cent	92 per cent
Lighting	33 per cent	61 per cent	6 per cent
Municipal	2 per cent	2 per cent	2 per cent

Dissimilarities in transportation demands in the same districts is also very pronounced:

	Northern	Central	Southern	Total
Rapid Transit	15%	75%	10%	60%
Pennsylvania Railroad	——	100%	——	40%
	10%	84%	6%	100%

The combined transportation requirements are supplied jointly by Philadelphia Electric Company (46.5 per cent), Philadelphia Rapid

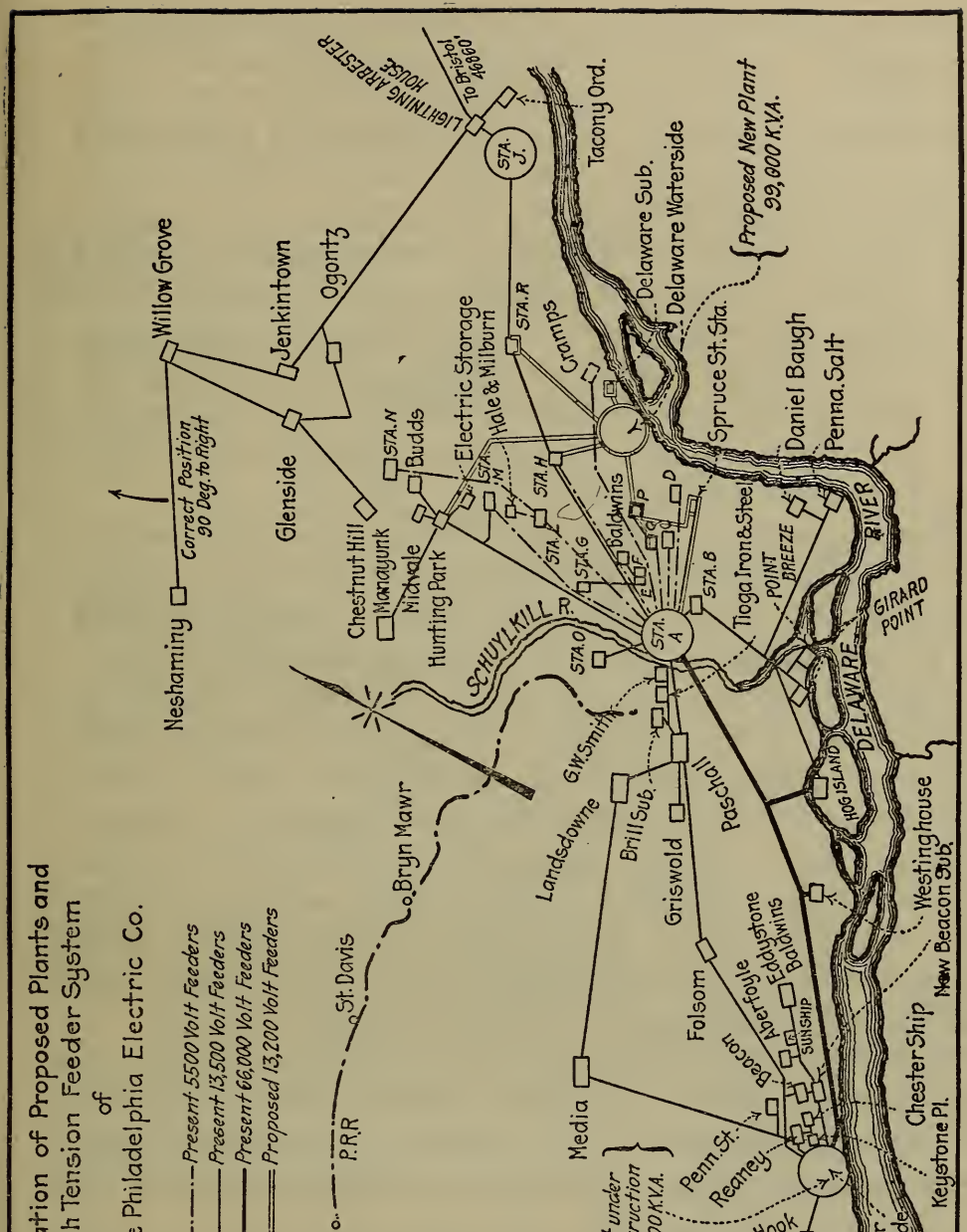


FIG. 10.—MAP OF THE PHILADELPHIA DISTRICT

Representing plan worked out during the war to provide adequate power supply in the district involving completion of one plant and creation of another as approved by Power Expert of the Emergency Fleet Corp. and now in effect.

Transit Company (52.3 per cent) and the Hydroelectric Company (1.2 per cent).

The growth of the demand similarly is unequal in different dstiricts:

Northern	35.8 per cent
Central	28.4 per cent
Southern	35.8 per cent

While this estimate has been made during the war in anticipation of certain special requirements, it may serve for elucidation of

the reasons for the selection of certain localities for the additional generating plants. The greatest shortage was thus anticipated in the Northern District. With the construction of a new plant in the Southern District in progress, it will be necessary to transfer the surplus of generating capacity from the Southern District to the Central District through the 66,000 volt line and from thence together with the surplus capacity in the Central District, transfer it to the Northern District, through its substations for distribution. The electric company therefore plans the construction of a plant in the Northern District on the bank of the Delaware River, selecting for it a site where coal will be available both by rail and water, ash removal not difficult, water in abundance, neighborhood of predominating industrial character, etc.

Another interesting plan has recently received the Parliamentary sanction giving the Manchester Corporation the right to proceed with an electrical scheme, which has become necessary owing to the rapid increase in the demand for electricity in the Manchester (England) area.[45] Figure 11 gives a general idea of the relative location of the proposed plant to the existing net of substations through which the territory is served. The project was described thus: "At the present time the city is supplied from three generating stations—Dickinson and Bloom Street stations, which supply direct current in the centre of the city with a combined plant capacity of 14,000 kilowatts, and Stuart Street station, in the Clayton district, which supplies alternating current at 6,600 volts pressure to numerous substations, and has a plant capacity of 55,500 kilowatts.

"In connection with the Stuart Street station there are 22 substations—excluding those on consumers' premises—with an installed capacity of 33,000 kilowatts. One of these is at Dickinson Street, where the generating plant was unequal to meeting the demand for electricity in the adjoining area.

"To meet the requirements of the large power users, the Corporation has also equipped 58 substations on consumers' premises with an installed capacity of 34,500 kilowatts.

"The area over which supply powers are held now amounts to 46 square miles, with an estimated population of 750,000, exclusive of the Middleton area, to which a bulk supply is given.

"The electrical demands of the area can be gathered from the fact that nearly 155 million units were generated and 118 million units sold during the year ending March 31, 1914 and that the maximum demand of about 50,000 kilowatts is increasing at the rate of some 5,000 kilowatts a year under normal conditions. All

the existing stations are limited in capacity by reason of water facilities for condensing purposes, and the existing buildings at Stuart Street will be full up with an installed capacity of 60,000 kilowatts the adjoining spare land being required for coal-storage purposes.

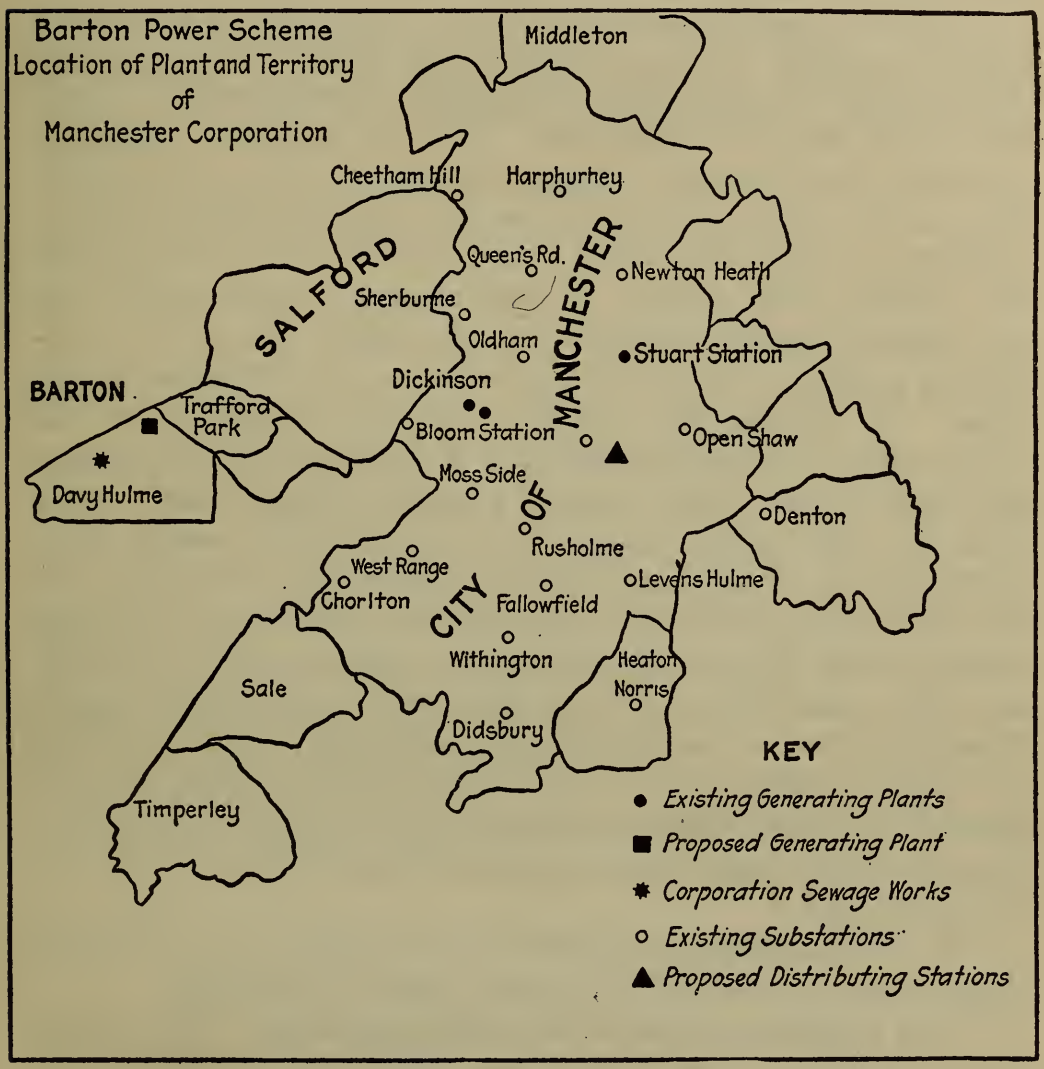


FIG. 11.—BARTON POWER SCHEME

An interesting example of a pioneer English project of comprehensive developments of electrical zone.

"In view of the limitations mentioned, particularly as regards the Stuart Street station, the effective capactiy of which for generating purposes will be reached when the maximum demand attains to 45,000 kilowatts, allowing for reserve plant, it was decided that further generating plant in a fourth station should be available by the summer of 1917.

"With this object in view numerous sites were inspected by the representatives of the Corporation, who were faced with a problem considerably in advance of anything yet attempted in the way of municipal electricity supply, as the project ultimate capacity of the new station will be some 160,000 kilowatts.

"The site actually selected for what is now known as the Barton generating station covers 12 acres, and is situated at the extreme western end of Trafford Park, on the side of the Bridgewater Canal, and in the parish of Davyhulme. This site fulfills the necessary conditions as to fuel, water, length of transmission lines, and foundations, as by means of the Bridgewater Canal the West Lancashire coalfields are easily accessible, being only four miles away, while the Trafford Park railways provide through communication with the English coalfields generally. In the matter of water for condensing purposes, the site is also convenient to the Manchester Ship Canal. As, however, the consent of the Canal Company to the use of the water is at present withheld, it is proposed to use the sewage and subsoil water—in the form of a purified effluent—which passes down the main outfall sewers to the Corporation's sewage works at Davyhulme, situated at some 1,400 yards from the Barton site. The Barton site is about five miles from the centre of the city, being actually nearer than an alternative site within the city area, which met with some favour; trial borings have also shown as regards foundations that red sandstone rock underlies the whole of the site at a depth ranging from 7 to 8 feet, and further, there are good grounds for considering that at least one and one-half million gallons of good quality water can be pumped from boreholes in this rock every 24 hours.

"It will be necessary to construct a new bridge across the Bridgewater Canal to carry coal and railway traffic to the station.

"The preliminary plans of the generating station which we are able to reproduce show that not only will it be the largest power station in the kingdom so far actually projected, but that it will be essentially a big unit station.

"Except as regards its adjacent situation, the Barton station will, under present arrangements, have no connection with the growing manufacturing area of Trafford Park, where at the present time, many concerns possess their own power plants, and the local power supply in the Park averages under 3,000 kilowatts, representing some seven million units a year.

"We believe it is no secret, however, that the existence of the huge plant at Barton, in close proximity to the Ship Canal and

this favoured manufacturing area, is expected to label to far-reaching developments in the future." [45]

The similarities and differences of these two cases may easily be gathered from this brief review and the interplay of causes in meeting the fundamental requirements as to location of a plant is in every individual case so complex and its effects on the success of the undertaking and on the managerial problems so profound and lasting that the greatest caution should be exercised both in selecting the site and in studying its influence on the operating practice.

Chapter III

THE EQUIPMENT OF PLANTS

THE physical characteristic of a power plant is determined by three main factors:

1 Location of the plant and its fitness for the service
2 Arrangement of units in relation to one another in space
3 Inherent efficiency of equipment.

A power plant may be defined as a mechanical installation, which is capable, under human will, of transforming a certain form of incarnate energy (either potential or dynamic) into some other desired form of energy, within predetermined time and space. From this broad definition it is quite evident that an almost endless variety of power plants may be further characterized according to the nature of transformation (electric substations are excluded as they handle the same form of energy and merely changing its characteristics), as to the quantity of energy handled per unit of time, as to percentage of losses sustained during the process, as to the costliness of performance, etc. In this manner a plant might be described as "a carboelectric generating plant of 50,000 kva capacity, 12 per cent thermal efficiency, generating 2,300 volt, 60 cycle, 3-phase current for 0.3 cent per kilowatt hour gross operating expense, and 0.75 cent total cost while running at 70 per cent load and machine factors, etc."

Power Plant Lay-Out

While generally speaking the machinery can be moved, in a power plant the re-location of unfortunately placed equipment is practically prohibitive due to excessive cost of rearrangement of special foundations, flumes, piping and other permanent parts of buildings. In this sense the lay-out of the plant equipment is a highly important factor which permanently affects the economy of operation. The elements of this order may be grouped as follows:

A Unloading and storage of fuel
B Handling of fuel and refuse
C Visibility of equipment

D Accessibility of all parts
E Space for repair work
F Grouping of units
G Centralization of operation
H Compactness
I Safety
K Comfort and hygiene.

We will briefly review some of the salient points of each.

A. The cost of *unloading and handling coal* varies widely, depending on the facilities available; whereas in one plant coal is unloaded from the barge directly into an overhead bin in the boiler room, in another plant coal may be shoveled out from the cars, carted to a pile, then carted when needed to a shed near the boiler room and wheeled in as used. There is equally great dissimiliarity in the means and capacity for storing coal. While not generally recognized, the coal stored in excess of safe precaution against transportation disorders, represents in itself an idle investment and in figuring out the overhead on coal unloading and handling equipment, rent on yard, etc., interest on coal pile should be taken into account. Effect of storage of coal on its efficiency will be treated elsewhere.

B. *Handling of fuel and furnace refuse influences* the cost of operation in a still greater measure. Equipment for weighing and feeding coal to the furnace, as well as for disposing of soot, ash and clinkers is in some instances so costly as not to offer any advantage over manual handling, in other cases no expenses should be spared in order to avoid danger of interruption of service or damage to furnaces by installing additional facilities of this kind. In practice one meets extreme range from ash hoppers so small as to necessitate the continuous work of a gang of ash wheelers, to elaborate mechanical conveyors, standing idle 94 per cent of the time. Which may be the correct way under the circumstances, depends entirely on the local conditions but it is beyond reasonable doubt that in each individual case this part of the plant equipment exercises a definite influence on the operating cost.

C. The *visibility of equipment* does not mean merely good illumination. With a limited number of attendants, which is common in modern plants, the arrangement of units and especially auxiliaries is often such that the plain view is obstructed by other machinery, pillars, walls, etc., thereby either jeopardizing the safety of operation or necessitating extra employees.

D. The *arrangement of equipment* is frequently made without due regard to its accessibility. What it means to get to a suddenly stopped vacuum pump in a hurry when it is located in a cellar with dark slippery stairs leading down from the opposite end of the engine room, jumping over a few pipe lines, crawling under electric conduits, squeezing between a tank and the wall before one can reach it, is known from experience to many operating engineers. To do repair work on the unit with parts inaccessible, with no room to use a wrench, etc., is another feat. Many accidents easily preventable with accessible machinery occur due to poor layout; still greater losses in operating economy are often due to the same reason: delay of repairs, postponement of unpleasant work and disregard of coming trouble.

E. Closely connected with these handicaps of poor layout is that of *lack of working space* around the machinery undergoing repair or overhauling. Lack of head room to take out tubes from vertical boilers, lack of space to remove pump runner or piston rod or replace economizer or condenser tubes are not infrequent in the plants built by inexperienced architects or jobbing contractors. What such handicaps mean in the increased cost of maintenance is almost insignificant compared with the losses of time in production, and moreover with operating losses accumulating while the repair on a defective piece of apparatus is constantly postponed because of the difficulties anticipated.

F. *Grouping of units* is another fundamental requirement for the successful operation of the plant but which seldom receives due consideration from the builders. Proper layout of piping, valves, and meters are essential not merely for timing the schedule of repairs on the boilers and turbines so as not to interfere with the regular operation or accuracy of records but it is often a matter of safety. Inability to separate productive groups and units is innumerous cases responsible for poor operating economy and quick deterioration of the equipment.

G. The principle which we call *centralization of operation* is comparatively new. Its early demonstration may be found in switch boards with remote controls of turbines, etc. In small plants this is carried sometimes to an absurdity by placing pannels on a balcony thus doubling the crew without gaining any advantage. In boiler houses however the principle of centralized control of operation is almost entirely unknown, yet the apparent advantages of having the control and regulation of combustion and steam generation centralized

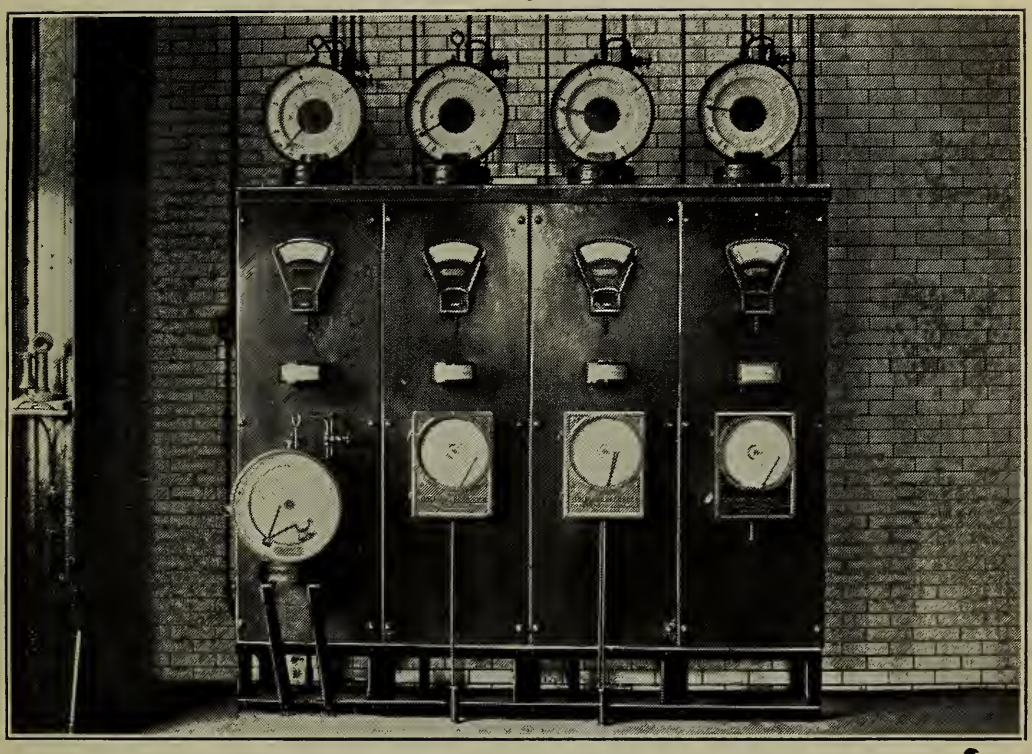


FIG. 12.—CENTRALIZED INSTRUMENT BOARD

In boiler room practice the principle of centralized control board is of recent origin. This board consists of four panels centralizing battery of four large boilers. Indicating flow-meters, draft gages and flue gas pyrometers show conditions in each boiler unit; temperature of feed water and of superheat and steam pressure are recorded for the battery as well as chart-drawing; integrating flow meter records total output. Gas analyzer is in the rear and telephone to the left keeps boiler room foreman in touch with the rest of the plant.

FIG. 13.—NON-SLIPPERY WALKS AND RAILINGS

It is important to provide safe and convenient gangways around the boilers valves, machinery, etc. There must be always plenty of work space around, good ventilation, and it should not obstruct light.

on one central board, as shown in Figure 12, operated by trained firemen or a combustion engineer are amply demonstrated in the author's practice.

H. *Compactness of plant layout* without crowding with resultant inaccessibility of equipment for operation, inspection and repair is a hard problem to solve. The evident advantage of its successful solution lies of course in reduced rent, smaller distances to walk through for operators, and further advantages for extensions. Otherwise, however, this factor has little bearing on operating economy and methods save for the reduced expense of cleaning, lighting, heating, and the like.

I. The importance of *safety arrangements and devices* is so well recognized that it is hardly worth while to enlarge upon the subject. In large plants, and superpower stations, explosion proof walls and gaps and separate "unit" installation are fully recognized. Non-slip steps, as shown in Figure 13, special precautions and arrangements in high tension room and transformer cells, protection against bursting tubes or excessive wind pressure in furnaces liable to burn firemen, etc., are all well known and have no little bearing on the amount of liability insurance. First-aid facilities for the use in treating the minor injuries that are liable to result in blood poisoning, blisters, etc., are of course a purely administrative function and will be treated elsewhere. Figure 14 reproduces an actual case of protection rendered by goggles.

K. Layout of the plant with due regard to *hygiene and the comfort of the employee* is the paramount requirement not only from a humanitarian but from an economic standpoint as well. Men actually live in their places of work, and too much attention cannot be paid to hygienic requirements. Petty annoyances caused by lack of comfort distract attention from the proper performance of work by occupying men's minds with schemes of avoiding inconvenience. Such elementary requirements as good, cool drinking water, comfortable baths, lavatories, dressing rooms, plentiful illumination free from glare and flickering, absence of cold drafts, good ventilation, dust prevention, restful seats, etc., are even more important than refinements in design and thermal efficiency of equipment. Tired, annoyed men with distracted attention, will overlook or even cause greater losses than the difference between the best and the next best efficiency of equipment. Firemen invariably increase their efficiency from four to five per cent under improved hygienic conditions. Figures 15 and 16 illustrate the kind of resting facilities com-

monly found in the average boiler plant. Anything that can be recovered from a junk heap to serve as a seat, so important for men after strenuous work at slicing, breaking clinkers or cleaning fires, is used and it does not answer the most modest requirements of hygiene, comfort, and decency. Figure 17 represents an attempt by the plant management to provide firemen with permanent and more or less restful seats and while these are not to be compared with office furniture, the expression on the faces of the occupants suggest a measure of contentedness.

Common Faults of Arrangement

The consideration of the influence of equipment on the cost of power would be far from complete without reference to that much neglected question of arrangement of equipment in a power plant and the location of the plant itself. The location of power plant in or among the factory buildings has a great deal to do with economy of operation and in addition, quite materially affects the cost of power at its ultimate place of consumption. As is often the case in an old and growing concern as demand for power, light, heat and ventilation grew with the development of the business, the necessary additions are made not in accordance with a well defined plan but when and as expediency demanded. Boilers and engines are stuck here and there; piping rivals in complexity the ancient Labyrinth; work is frequently done without any drawings; equipment is selected not for its fitness but for its availability at the time and is sometimes located even before the housing is erected; and the consequences are sometimes so serious that scrapping of the entire old equipment and the erection of a new plant is more economical than the continuation of waste of energy and material in the old plant.

Scattering the equipment in an uncentralized plant requires more operating labor, makes repairs difficult, handling of coal, ashes and materials expensive, supervision inconvenient, accidents more likely, rent higher, frequent interference with manufacturing, etc.

Piping in such a case is unnecessarily long with corresponding losses, the frequently confusing tangle of branches, etc., is unfamiliar to employee with the result of leaking valves, inoperative traps, excessive number of bends, reducers, etc.

Absence of isometric or perspective diagrams causes much confusion in inspection, neglect in operation, danger and delays in emergency, etc.

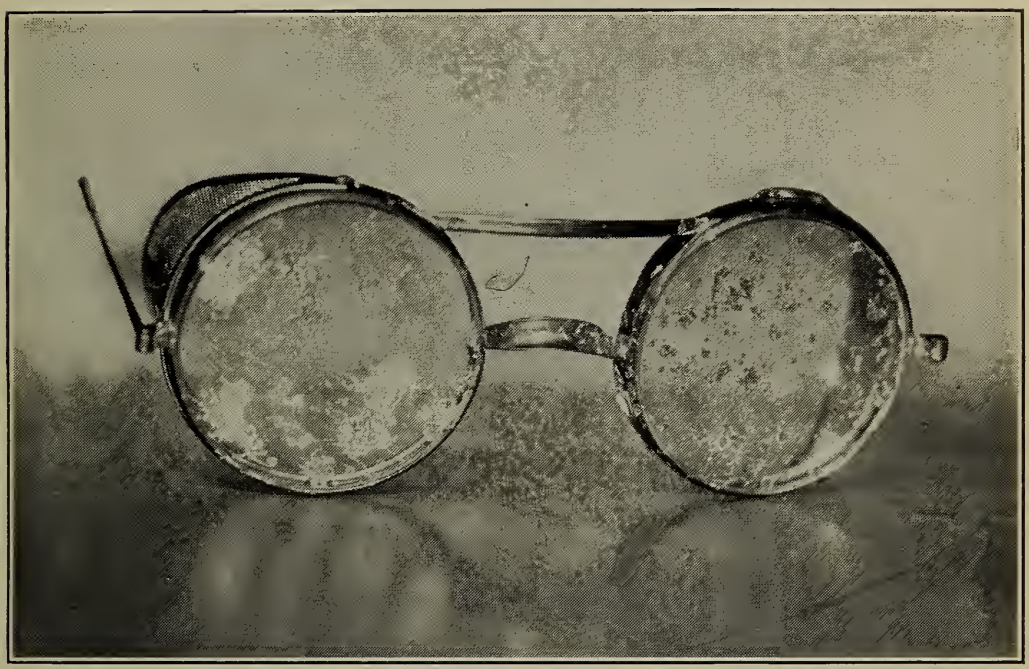


FIG. 14.—GOGGLES THAT PROTECT

The use of these goggles in one of the plants under our supervision actually saved eyesight of a mechanic. General superintendent issued following statement after the accident:

Notice

On Monday, October 21, 1918, Nathan Rice was pouring babbit in a bearing in the Machine Shop after heating the bearing with a blow torch and taking all possible precautions.

The babbitt blew out of the bearing for some unexplained cause and covered his face and goggles as you can see in the attached photograph.

Without goggles he would probably have lost the sight of both eyes.

Remember this lesson and don't make it necessary for your foreman to tell you to wear goggles when pouring molten metal, chipping or grinding. It is even more important to you that your eyesight be unimpaired, than to your employer.

DON'T FORGET THOSE GOGGLES

Poorly proportioned capacity, or equipment ill adapted to the service required, or character of power unsuited to the work, not only unnecessarily increases the cost of generation of power, but is frequently a cause of spoilage of goods manufactured. It sometimes impedes the manufacturing processes as, for instance, in the case of uneven speed in a belt-driven apparatus requiring uniform speed, or of the use of a motor the speed of which is affected by voltage and load, or the use of pneumatic rather than electric or steam power, fluctuations in steam pressure and temperature, the use of live steam where exhaust would do, etc.

Finally, not infrequent instances are found where repairs or replacements cannot be made on account of the lack of room around the machinery, building being completed or even built after the machines already have been installed.

In the endless variety of such cases, the relocation or remodeling of generating equipment, means for transmission of power, etc., is frequently inadvisable for some reason or other, such as lack of space, lack of capital, loss of production during reconstruction and the like, but whenever such a remodeling is possible and advisable from the economic standpoint no architect or contractor should be called in on the job until after manufacturing men have presented their requirements to a power specialist and he has worked out the specifications and plans from which both operating results and necessary layout of equipment can be definitely predetermined. Again, in certain localities and in manufactures not requiring steam for processes, additional studies should be undertaken to ascertain whether purchase of power on a long term contract would not be the best solution of the problem. This question will be analyzed in detail later on; in passing be it noted that the "free reports" offered by new business departments of some public utility companies have often a strong smack of "cure-all" patent medicines recommended by some unscrupulous druggists.

It is not the author's purpose to deal with any specific and concrete description of plant equipment, machinery, instruments, etc., as these matters are fully covered in various catalogues, bulletins, and manufactuers' literature; he is merely concerned with such characteristics of the physical properties of the plant equipment and its layout as affect functional conditions and permanently influence the methods and results of the operation. It is timely and proper, to recall however, at this point, the effect of sanitary and hygienic surroundings of work, arrangement of machinery and safety appliances, on the greatest and least excusable waste of all-waste of

human happiness, health, and life. While statistics of industrial accidents, such as boiler explosions, electrocutions, mangling of limbs, burns and scalds, falls, etc., is fairly complete and more or less known, impressive in its figure which exceeds half a million per year, we as yet know little of industrial diseases and, their prevention should be a field for a broad coöperation between engineers and doctors. An appallingly large number of rejections of drafted men because of their unfitness for military service is the strongest possible condemnation of an economic system that ruins the future of the country and undermines health and prosperity by neglecting the public health. Referring to similar conditions in England, Lloyd George expressed the fear that a nation whose working class must live in conditions creating weakness and diseases cannot hope for any measure of success. In the United States where the number and percentage of accidents on railroads and in mines and in industry is perhaps the greatest in the world, the warning should assume the proportion of an alarm, particularly since the European immigration does no longer refill the ranks of killed and maimed.

Characteristic of Equipment

As we approach the third group of permanent physical characteristics of the power plant—that of efficiency of equipment, thermodynamic or other, we feel justified in again emphasizing the fact, that under the existing peculiar financial conditions, the mere thermodynamic perfection of equipment many and often times does spell a lowering of commercial profit-rate.

Let us assume two installations one A consisting of two 2,500 kilowatts turbo-generator units bearing $9,000 cumulative annual fixed charges, and an installation B of one 5,000 kilowatt unit with fixed charges amounting to $7,500 per annum. Since the smaller units at full load would consume 15 pounds of steam per kilowatt hour whereas the larger one only 13 pounds per kilowatt hour with the cost of coal at 22¢ per 1,000 pounds of steam the annual output of 10,000,000 kilowatt hours, the fuel saving would be theoretically $33,000—28,400=$4,400 per year in favor of the larger and more efficient unit, and adding economy in fixed charges ($1,500) the gross saving would appear as high as $5,900 per year. The fallacy of such a calculation is, however, easily exposed if we consider that for our annual output the larger turbine will show the advantages of full-load efficiency only temporarily during peak loads, the average steam consumption per kilowatt hour being in accordance

FIG. 15.—SLOPPY BOILER ROOM

Work of the men is greatly handicapped by untidy upkeep of the work place. Coils of hose, puddles of water, firing and cleaning tools scattered over the floor and dilapidated seats without backs add to discomfort and fatigue and create the atmosphere "I don't give a darn."

with its water rate curve close to 20 pounds per kilowatt hour, whereas in case A most of the time only one turbine will be running at nearly full load (15 pounds per kilowatt hour) with the average steam consumption of about 17 pounds per kilowatt hour. Now, the true cost of coal per year for the same output and the same typical load-curve appears in case A as $37,400 and in case B as $48,400 or $11,000 in favor of the more expensive and thermally less efficient installation. Subtracting from this gross saving the excess of fixed charges ($1500) we still have a net gain of $9500 per year, instead of $5900 loss.

In short, conditions such as nature of service, average load, percentage of idle time, probable future load and output, etc., swing the balance of such and similar comparisons in such a marked degree that one cannot be too careful in estimating the influence of thermodynamic perfection, and the first cost of equipment, upon its ultimate effect on cost of operation. Similarly the much discussed influence of auxiliaries on the ultimate economy in a steam power plant should be first carefully studied from the heat balance viewpoint, since under certain conditions the benefit of high temperature boiler feed, effect of economizers, high vacua, etc., may in the last count offset the apparent advantages of high-economy apparatus if judged in themselves.

The relation between the thermal efficiency of a plant's equipment and operating economy is thus a question which under existing economic conditions does not permit a rigid definition or any specific rule. The operating economy due to the higher thermal efficiency of a unit may be entirely offset by increased capital charges incident to this improved machinery; again cases are on record where the employment of large size unit of high thermal efficiency is decidedly disadvantageous when its use is limited to only a few hours a day, or when the unit is operated most of the time at the load resulting in poor economy. This is particularly true in plants handling an uneven load and a most painstaking selection of sizes and character of generating units is of great importance, while in plants carrying regular, well diversified load, the problem appears fairly simple. Figure 18 represents two very dissimilar load curves carried by two well-known public utilities and even the most superficial observation suggests the necessity of employing radically different equipment for carrying economically either one or the other load. When we come to consider the electric railway plant or factory power plants, the dissimilarity of requirements have a still more pronounced effect on the selection of equipment both from the viewpoint of economy

and service. It is obvious that the selection of equipment must begin from consideration of prevalent load curve modified by seasonable variations and probable future development. Figure 19 illustrates a well-known example of a plant handling an average load of 40,700 kilowatts with 72,000 kilowatts maximum hour,[46] comparing its electric output curve with the heat input. Mr. R. J. S. Pigott in a paper before The American Society of Mechanical Engineers presented a simple and in many cases serviceable method of graphic presentation of performance of plant equipment, either separately for every unit and its auxiliaries or for the entire plant.[47] There can be no doubt but that this and similar methods of graphic analysis in steam power plants, are not only essential for an intelligent design, but are particularly valuable from an operating viewpoint.

Capabilities of equipment carefully studied and clearly represented in the form of plain curves are very helpful in:

a Selecting suitable equipment for service from the veiwpoint of the adoption of the most economical, thermally efficient and reliable equipment.

b Devising operating practice, i. e., mode of use and number of units needed for every variation of demand

c Controlling the performance, enabling an accurate comparison of what was done with what could be done

d Comparing operating results of physically dissimilar plants in order to learn how close the actual performance corresponds to the predetermined individual plant standard.

Figure 20 refers to the case represented in Figure 19 and from a study of existing characteristics of equipment, the author was able to conclude for instance, that by means of heat balancing the total required input of 19,823,300,000 B. t. u. may be reduced to 19,630,800,000 B. t. u. per day, or roughly to accomplish an annual coal saving of 2750 tons.

Much more elegant and broadly applicable method was afforded by R. H. Smith, based on a theoretically complete and satisfactory formula with nine constants, which makes the two rates of cost vary with size and with pressure, namely:

$$K_{s_2} = K + \frac{K_4 + K_5 P_1}{(K_6 + S_2)^2} + \frac{K_8}{k_9 - P_1}$$

$$K_p = K_3 + \frac{K_7 + K_8 S_2}{(K_9 - P_1)^2} + \frac{K_5}{K_6 S_2}$$

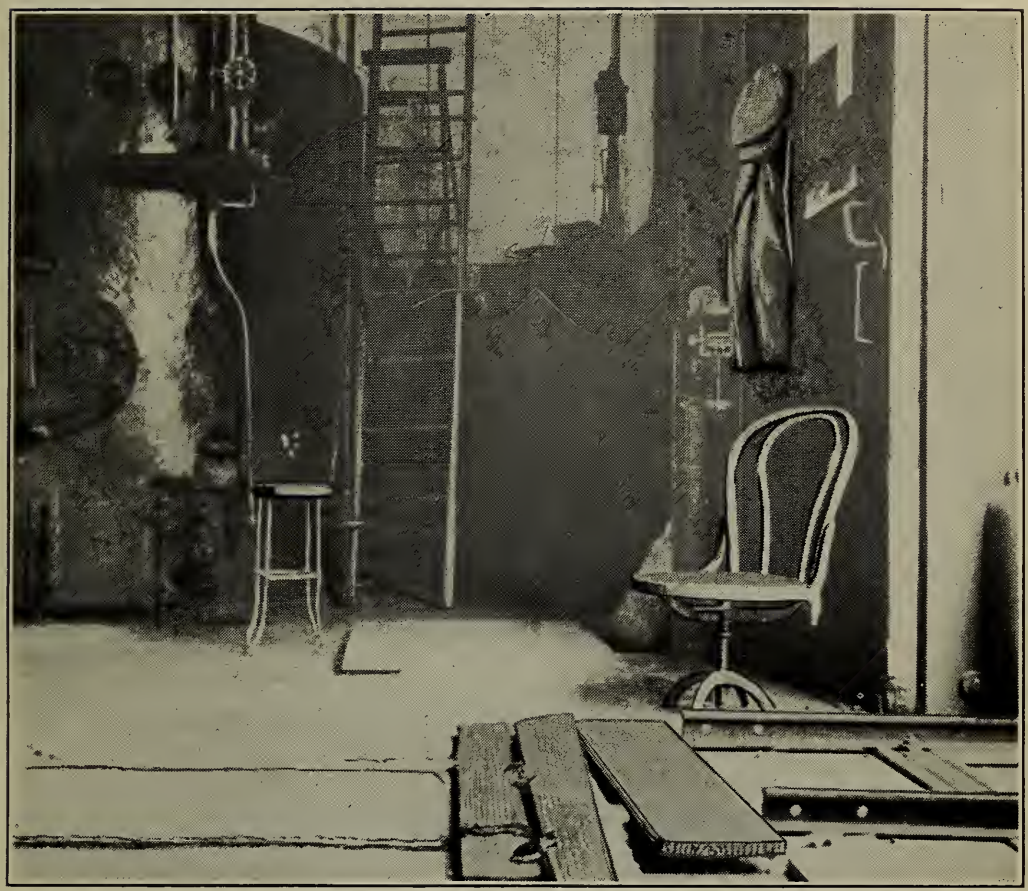


FIG. 16.—EVERYTHING FOR DISCOMFORT

Bad arrangement for wheeling coal in over the loose planks, uneven rails, etc.; no provision for direct weighing of coal; scales out of the way; makeshifts for seats and no lockers for clothing. Ladder unprotected.

The second differential coefficient, showing the curvature of the surface diagram is:

$$K_{s_2}P_1 = K_{p_1}S_2 = \frac{K_5}{(K_4+S_2)^2} + \frac{K_8}{(K_9-P_1)^2}$$

Establishing thus the connection between work, heat, and cost, or more specifically relations of pressures (initial) and volumes (final) on costs, the formula is applicable to the calculation of most commercially economic combinations of the elements of design. The diagram, reproduced in Figure 21, constructed on this principle may be applied either to engines, boilers, condensers, gas producers, etc., separately or to complete plants of combinations of these.

In Smith's diagram, the pressure scale runs to 200 pounds per square inch and the volume scale to 100,000 cubic inches. The full and dotted lines are parts of the permanent diagram. The four long dash lines are the only construction lines needed to obtain the results for any desired particular pair of size and pressure values P_1 and S_2. Two of these lines are simply the lines of the cross-section paper and do not need to be drawn. The other need to be constructed though not by actual drawing, but simply by laying the edge of the set square in the correct direction through the origin O.

While those interested in this unique method should be referred to the source[49] it should be understood, however, that this formula and diagram may be applied equally well to prime costs or capital outlays, and to annual charges based on capital expenditures. Of course, the costs read from the diagram are different in the two cases, not only in numerical magnitude, but also in kind. In one case they are sums of money, in the other they may be sums of money per year, or money per year per horsepower, or money per unit of work, or money per unit of weight of working fluid used; and the unit of time involved may be a year, an hour, or a minute. The arithmetic magnitudes and the kinds of the constants K will differ correspondingly. Professor Smith has thus theoretically laid down "the elements upon which must be based the solution of the problem of maximum commercial economy. Of course, it can not be expected that such general solution should be extremely simple, because commercial economy is influenced by many concurrent factors. It is essentially a complex thing, and no theory of it which was very simple and elementary could possibly be true."

Several other methods of analyzing the effect of inherent efficiency of equipment on operating economy have been made by various writers putting stress on one or another phase of the question, of which Grinevetsky's method of graphic analysis of working process

of a steam boiler has so many useful applications that a somewhat lengthy description of the same is given in the Appendix, on page 425 while Figures 22, 23, and 24 represent solution of the problems by this method. Messrs. Stott and Gorsuch [50] offered an empirical method for compensating the effect of local dissimilarities of plants in their relative economy but unfortunately they treated this important subject too superficially and only for an exceedingly limited field of application. The writer approached the subject from a somewhat different angle in his earlier work on predetermination of power plant costs [27] and the method employed is described in Chapter X, relating to costs.[51]

The outstanding fact however is that in any case when the inherent efficiency of equipment is a factor, clear distinction should be drawn between the *theoretical maximum thermal efficiency* of a unit or combination of units and the *practically attainable maximum efficiency* as limited by local conditions in a given plant. For instance, the theoretical efficiency curve of the turbine may be several per cent better than the maximum attainable due to limitations created by condenser, worn out blading, etc. Thus, for instance Figure 25 represents the deviation of actual performance test of a two-year old turbine from the theoretical or rather "guarantee" performance, while turbine test curves, Figure 26, obtained by experiments were more or less a surprise and various theories have been advanced to explain unexpected dip at 26,000 kilowatts load and another at an overload. Lastly Figure 27 represents a comparison of actual thermal efficiencies of six power installations, as obtained and published by different observers; balancing fixed charges per hour against capitalized B. t. u. input in each case may serve as a rough guide for a selection of the best commercial economy of installation.

On the other hand in all such questions confusion must be avoided between maximum thermal efficiency and maximum commercial economy, the criterion in each case being different. It is very often the case that the operation of a plant at its maximum thermal efficiency is less economical from the dollar viewpoint than at somewhat lower thermal efficiency. This consideration brings us face to face with the effect of the time-factor in production on one hand and with the necessity of a separate and distinct treatment of the greatly confused conception of "economy," on the other.

Economic Conception

In order to be able to accurately measure the economic advantages of the various means of production employed, we must first agree

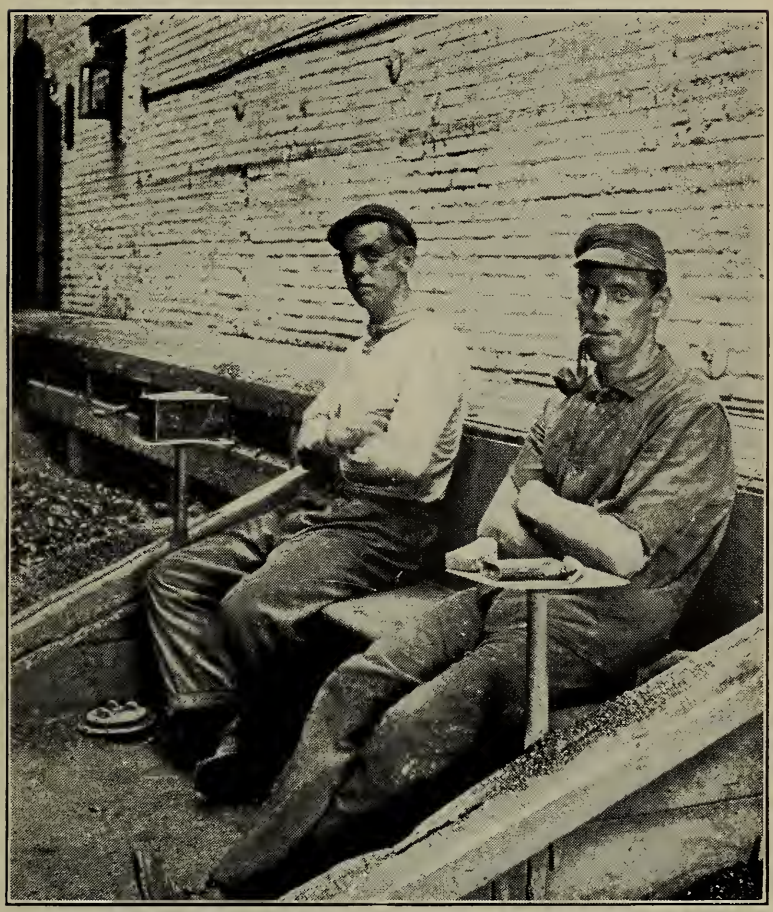


FIG. 17.—RESTFUL SEATS FOR FIREMEN

Even such simple arrangement for seats between coal bins is an improvement. Bench is provided with back both for rest and protection from draft from under gangway; stands provided for lunch box and smoking material. Note the posture and expression of men.

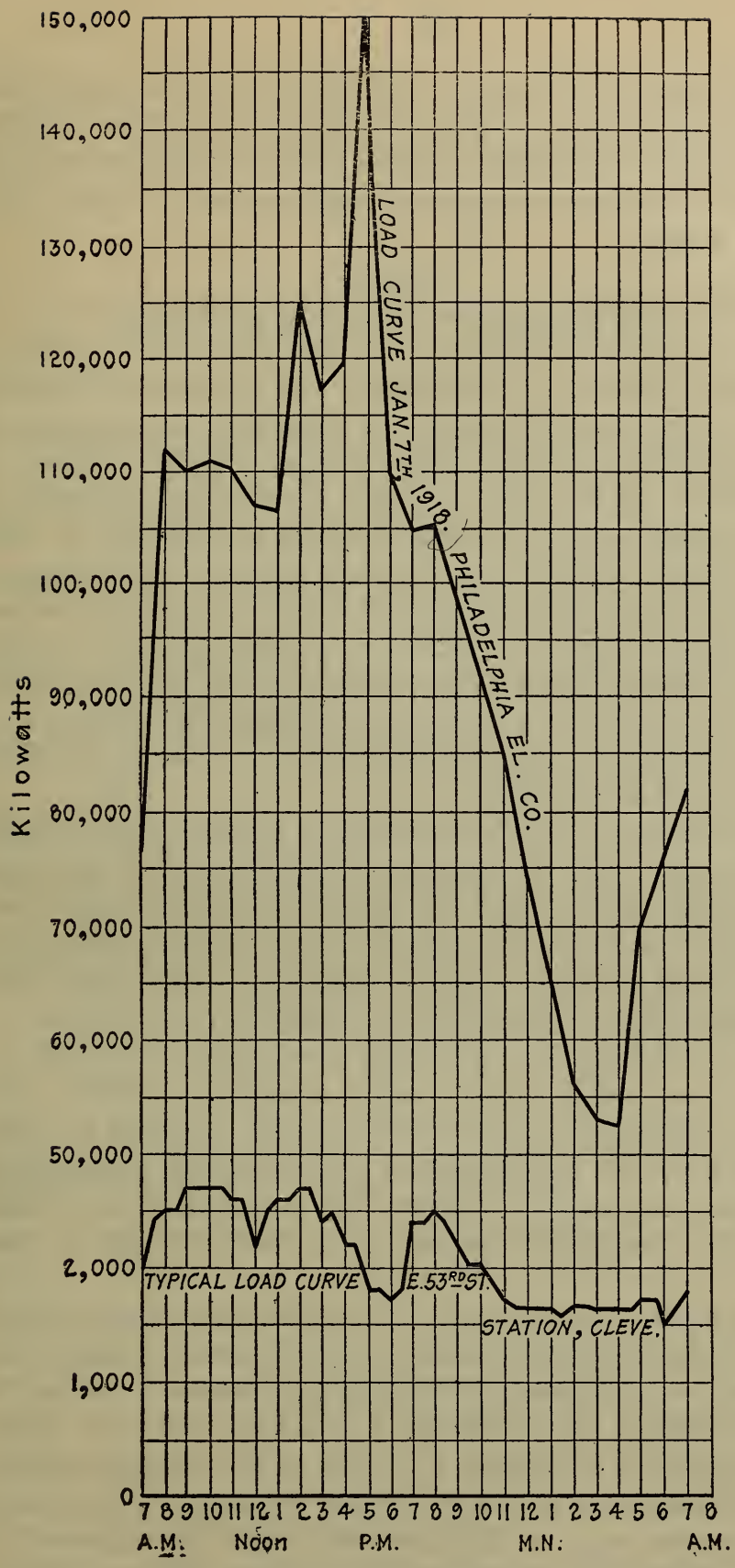


FIG. 18.—TWO CHARACTERISTIC LOAD CURVES

Any comparison of operating performance of these two electrical Central Stations would be fruitless of results unless the character of the load is taken into account. In a Philadelphia case, the ratio of maximum to minimum is 28.3 while in Cleveland it is 15.3. Moreover, the changes of load are rapid in the first case and slow in the other.

as to what constitutes the measure of economy. On the surface the proposition appears very simple: the product is a factor of time while the value of the product is also a factor of expenses incurred in production; therefore the economy coefficient may be simply represented as a ratio:

$$E = \frac{\text{Product}}{\text{Cost of production} \times \text{Time of production}}$$

This relation visualizes the well-known fact that the economy of production increases with reduction of manufacturing expenses or increased production per hour and decreases with the increase of time consumed. In the field of power production this relation is further accentuated by the thermo-economic peculiarities of some of the equipment engaged where further reduction of economy is caused by the increase of time required for generation, *i. e.*, thermal efficiency usually drops when the boilers, turbines, etc., are working below the capacity known as most economical load. Another specific limitation frequently enters the problem of power generation, *i. e.*, the drop of efficiency with the reduced time of production beyond a certain capacity limit (overload).

Thus even from a purely thermodynamic standpoint the economy of one or another type of equipment depends upon at least three variables: temperature (initial and ultimate), pressure (initial and ultimate) and time rate of production (rate of driving, load, etc.) Commercially the economy of a given equipment is determined also by (a) *fixed expenses* incurred by its ownership, (b) *constant expenses* involved irrespective of the rate at which it is used and (c) *variable expenses* representing the cost of operation at different rates of its usage. While the last two groups will be discussed at length elsewhere in this book, the expenses of ownership must be considered at this juncture as, generally speaking, they are unalterable by means of operating or managerial practice in the limited sense of those words.

While the plant and equipment is a tangible asset, it carries with it definite financial obligations such as rent on space occupied, housing, interest on investment, insurance, amortization of value of plant and equipment depreciated due to wear and tear, etc. Whatever the amount or percentage thus due to the landlord and the money-lender may be, it presents a definite problem. In its elemental form the problem may be illustrated as follows: one kilowatt of plant capacity carries N dollars annual burden; this one kilowatt capacity may be used either one hour during a year or 8760 hours

and hence, may be instrumental in producing anything from one to 8760 kilowatt hours of electric energy. The query is thus where, within the following limits, shall the overhead per unit of output be:

$$\frac{N}{1} > X > \frac{N}{8760}$$

Again the matter does not end with establishing the value of N as determined by all the tangible assets for there are various intangible assets, which also may be capitalized on the books and claim the

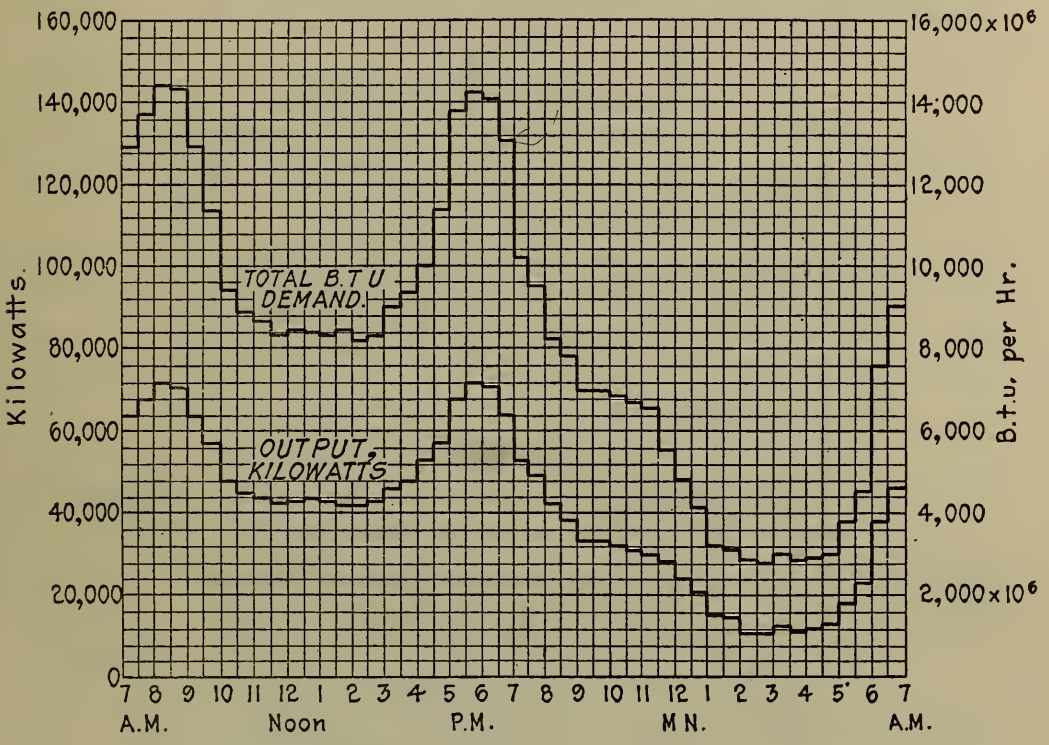


FIG. 19.—LOAD CURVE AND HEAT INPUT BALANCED

Diagram of half hourly demands for heat-energy and corresponding output in kilowatts for a representative day. Traction load.

right of earning income as soon as this ceases to be merely a bookkeeper's notation, and is covered with some form of corporation security, preferred stock or bonds for instance. If such is the case and this source of income is accepted and approved by the public authorities it becomes a legitimate overhead charge, and is counted among necessary costs and is included in N. Consequently, whatever the method of determining X which the consumer shall pay as portion of the price for the concern's offer of commodity and services, it is moved within higher limits.

On the other hand, if for the moment, we assume that the overhead or fixed charges should be *entirely absorbed* by some suitable

distribution over the product, whatever the output may be, the overhead per unit will be lowest with the maximum output and also with the minimum investment per unit of productive capacity, the latter however, as we have already seen, having an influential bearing on

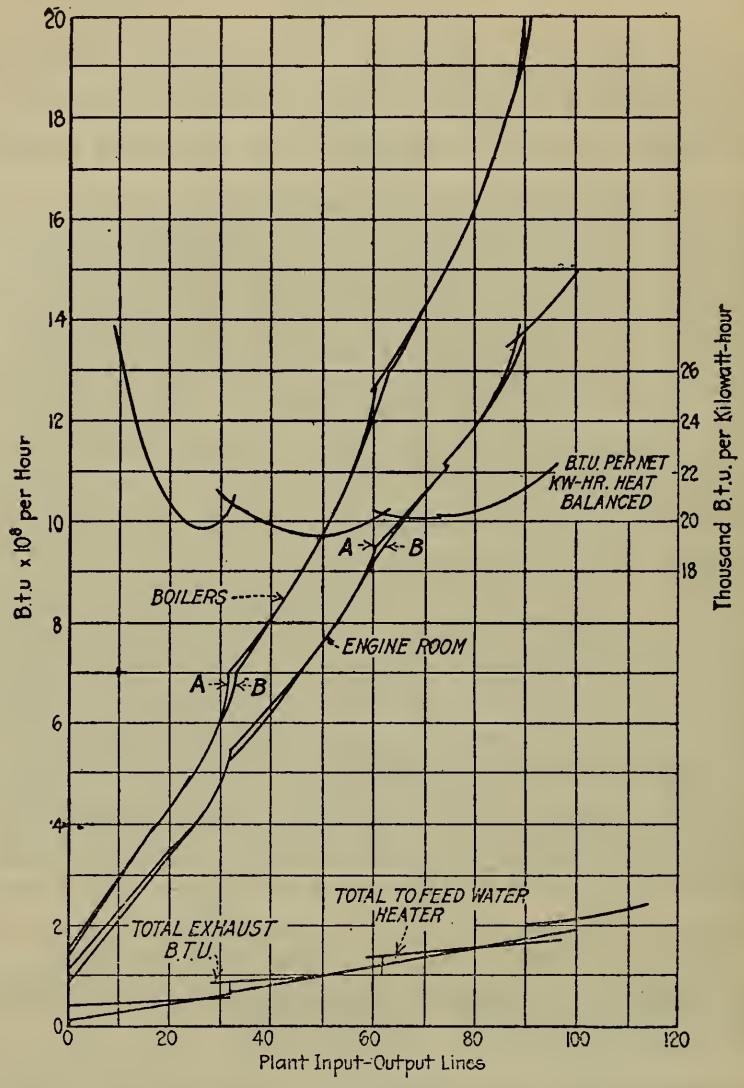


FIG. 20.—INPUT AND OUTPUT LINES OF A PLANT

A study made at the plant of the Interboro Rapid Transit Company of New York, shows these interesting economy curves. Note the waves in curve of B.t.u. per net Kwh. and compare them with the waves of our Standard Cost curves as shown in Figures 111–112.

operating cost as the first cost of more efficient equipment is higher than of that which is less efficient and more crude. The interrelation of these factors is no doubt a complicated problem involving a number of simultaneous equations determining final maxima and minima, the solution of which is hardly within the competency of

the average business man, banker or investment broker unaided by an engineer and mathematician.

An economist [52] observing the growing complexity of engineering means in the modern business world remarks: "All the while the

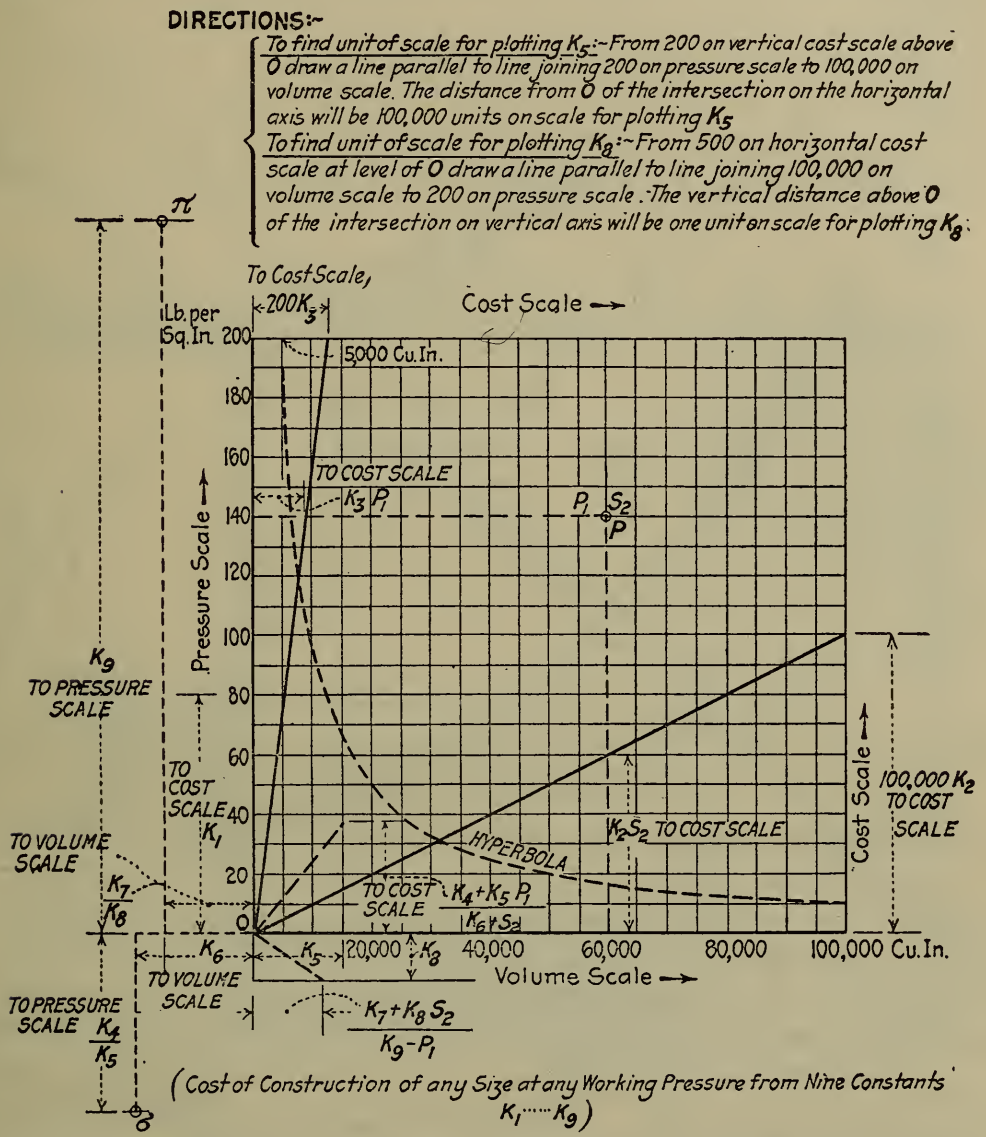

DIRECTIONS:-
To find unit of scale for plotting K_5:-From 200 on vertical cost scale above O draw a line parallel to line joining 200 on pressure scale to 100,000 on volume scale. The distance from O of the intersection on the horizontal axis will be 100,000 units on scale for plotting K_5
To find unit of scale for plotting K_8:-From 500 on horizontal cost scale at level of O draw a line parallel to line joining 100,000 on volume scale to 200 on pressure scale. The vertical distance above O of the intersection on vertical axis will be one unit on scale for plotting K_8
To Cost Scale,
$200K_3$
Cost Scale →
Lb. per Sq. In.
200
180
160
140
120
100
80
60
40
20
5000 Cu. In.
TO COST SCALE
$K_3 P_1$
P_1 S_2 P
Pressure Scale →
K_9 TO PRESSURE SCALE
TO COST SCALE K_1
TO VOLUME SCALE
K_7 / K_8
HYPERBOLA
$K_2 S_2$ TO COST SCALE
TO COST SCALE $\frac{K_4 + K_5 P_1}{K_6 + S_2}$
Cost Scale →
$100,000 K_2$ TO COST SCALE
K_6
K_5
20,000
K_8
40,000
60,000
80,000
100,000 Cu. In.
Volume Scale →
TO VOLUME SCALE
$\frac{K_7 + K_8 S_2}{K_9 - P_1}$
TO PRESSURE SCALE K_4 / K_5
O
(Cost of Construction of any Size at any Working Pressure from Nine Constants $K_1 \cdots K_9$)

FIG. 21.—SMITH'S DIAGRAM FOR THE DETERMINATION OF MAXIMUM COMMERCIAL ECONOMY

The description of the method is to be found in text and also in the book on Commercial Economy of Steam Power Plants by R. H. Smith.

progressive shifting of ground in the direction of a more thoroughly mechanistic organization of industry goes on and works out into a more and more searching standardization of works and methods and a more exacting correlation of industries in an ever increasingly large and increasingly sensitive industrial system. All the while the whole

of it grows less and less manageable by business methods; and with every successive move the control exercised by the business men in

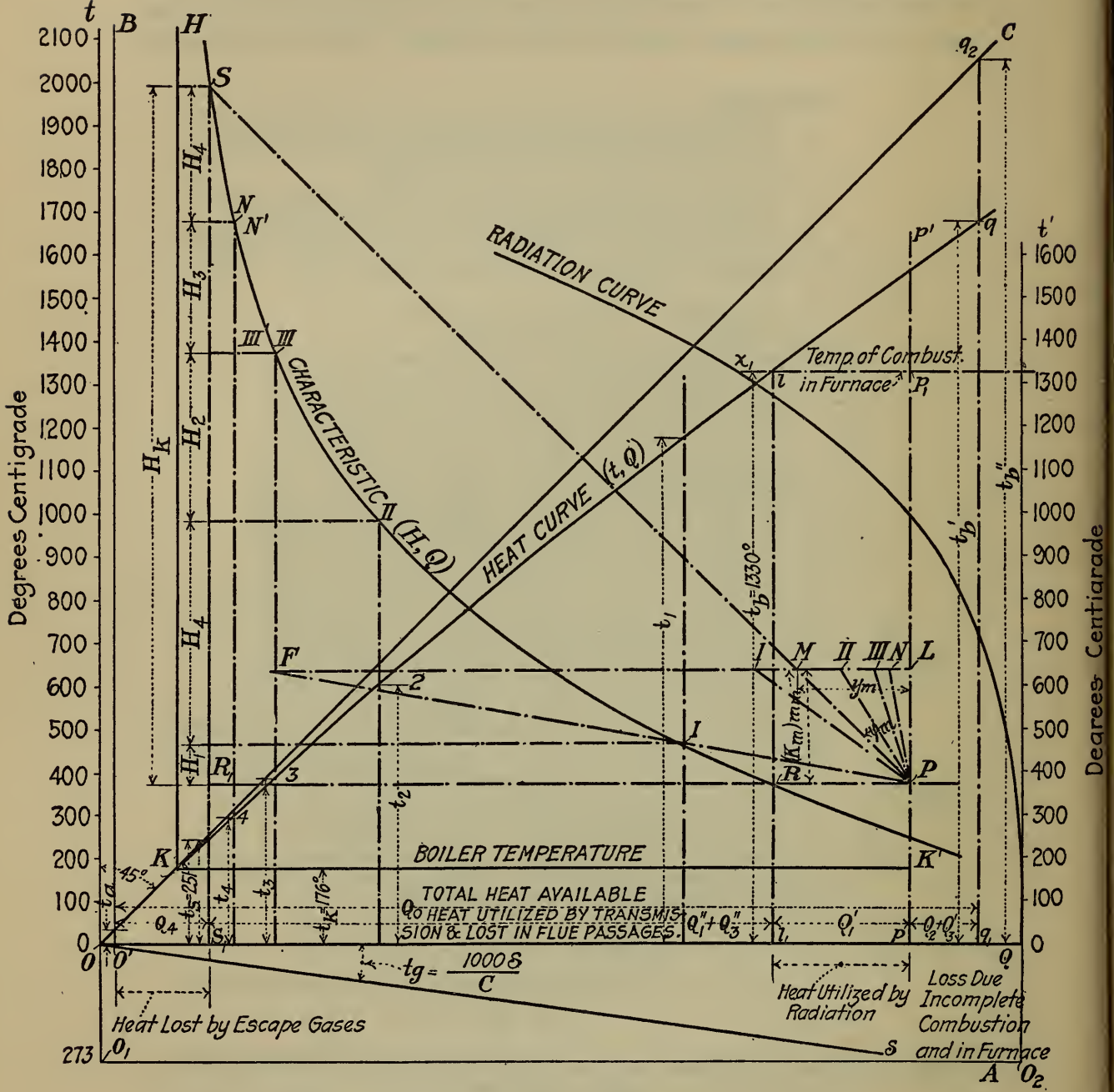


FIG. 22.—DIAGRAM OF A TEST OF A WATER-TUBE BOILER, GERE

129 sq. meters heating surface. Steam press. 10 Kg. sq. cm. Fuel—Fuel oil residue (for velocity of gases and rate of driving see Fig. 23).

charge grows wider, more arbitrary and more inconsistent with the common good."

In fact, if the only object in carrying on any industry were to

win profit, irrespective of what the conduct of this industry gives to the community, that industry would certainly die out of existence in a very short time. The common good, so far as it is a question of material welfare, is evidently best served by an unhampered working of the industrial system at its full capacity, without interruption or dislocation. The best negative proof may be had in examples of what is politely termed "panics" and business depression but what in reality are industrial crises caused by the race for profit irrespective of the welfare of the community at large. Under such

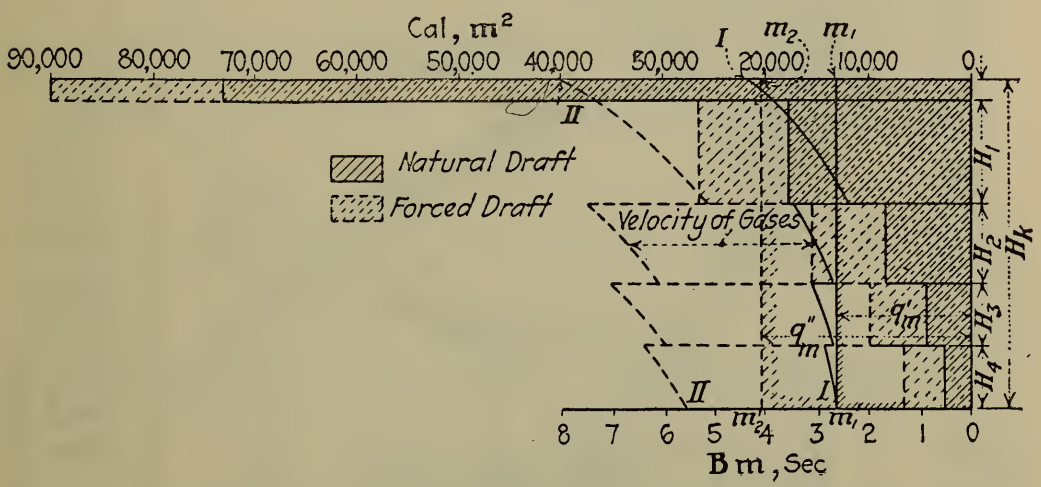


FIG. 23.—DIAGRAM OF RATE OF DRIVING OF A GERE BOILER AND VELOCITY OF GASES IN GAS PASSAGES.

conditions, concerns that assume a broader viewpoint in their perception of charging overhead to consumers and crippling their productive organization, are not only able to survive the crisis but can recover more quickly. The remarkable recovery of the United States after the Civil War was thus described by a business man of the period: "When the war ended we all knew we should have a panic, some of us like Mr. Hiar, expected that the greenbacks and volunteers would be disbanded together. Others expected gold to fall to 101 or 102 in a few days. Others saw a collapse of manufacturing industry owing to the cessation of government purchases. But we all knew a crisis was coming and having set our houses in order accordingly, the crisis of course, never came." [53] In fact Dunn's Agency reported only 500 failures in 1865 as against 5,900 in 1861, the liabilities in the 1865 failures likewise were only one-tenth of those in 1861.

Carnegie's success likewise was justly ascribed to his ability to understand the advantages of keeping his productive equipment and organization at work during the crisis though probably at a

sacrifice of overhead charges. With our task of to-day's in converting war industries to a peace footing the maximum production with the highest efficiency and corresponding lowest cost alone offers

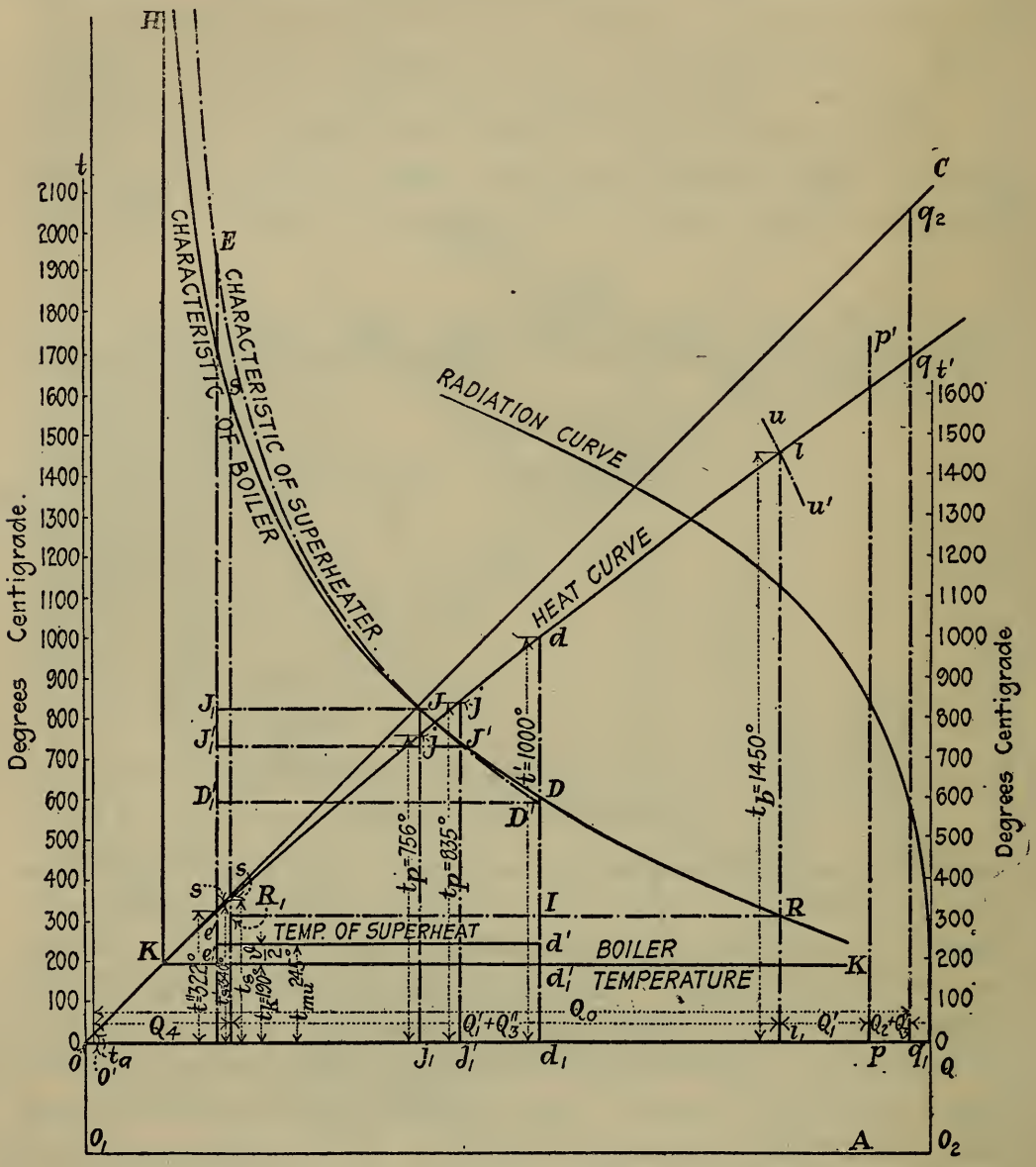


FIG. 24.—DIAGRAM OF A TEST OF A LOCOMOTIVE BOILER WITH SCHMIDT SUPERHEATER

Heating surface 106 sq. meters, superheater surface 28 sq. meters, steam pressure 13 kgs./sq. cm. Fuel—anthracite.

escape from industrial disorganization. In this work a thorough examination of the part the overhead charges are playing in fixing prices is of immeasurable importance, particularly bearing in mind that the idea of writing off the books the charges accumulating by equipment for which there is no work, in order not to make the price

of vendable goods prohibitive, is by no means unfamiliar in Europe. To carry on the product the fixed charges of parts of plant formerly used for war materials and which are not yet adapted for new demands would be suicidal. Moreover, to disregard this principle in the power industry, under an excuse that "it won't work" would harm the country as much as that industry itself since cheap and abundant power for industrial purposes has been proven to be the

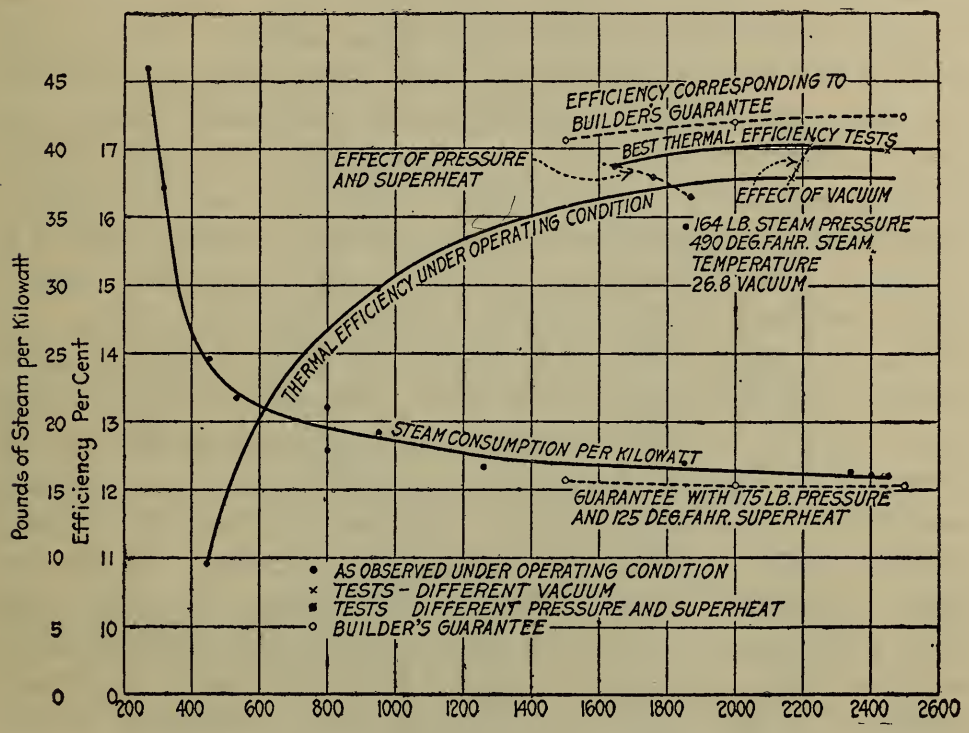


FIG. 25.—TEST CURVE OF CURTISS TURBINE

2500 Kw. turbine tested after several years of service showed decrease of economy. Effect of pressure, superheat and vacuum was studied at special tests, the summary of which is also indicated on the graph.

foundation of industrial prosperity, coincident with high wages and freedom from labor unrest.

As regards the European practice of "dumping," the following argumentation of R. H. Smith, professor emeritus of engineering in the Birmingham University, England, is of much interest.[54] "If the productiveness of certain plants has become greater than enough to supply the demand at ordinary prices, either by the increase of productiveness of the plant or by decrease of the market demand . . ., then the question unavoidably arises whether it is more advantageous to throw out of operation a certain portion of the plant or to increase the demand either by a general lowering of prices or by a spread of the market into new hitherto untouched

regions by sales in these new regions at specially low prices. The loss due to throwing part of a plant out of work is greater than the simple depreciation. . . . the *gross revenue* is diminished in proportion to the plant thrown out, but the establishment charges are lessened little or not at all.

"Now, if this loss by stoppage of plant thrown out of work be ascertained to be a greater than that incurred by selling at a lower than ordinary prices in extended markets then, as a matter of course, the lesser loss will be accepted as the best solution. These lower prices do not, even in the extreme cases, mean selling at below real cost; they mean selling at a profit upon the depreciated value of the plant. If this were not so, then the other alternative, namely that of throwing parts of the plant out of operation, would be adopted. The choice between the alternatives is, perhaps generally, decided in accordance with the exclusive interests of the shareholders, that is, without reference to those of the debenture holders or of the employees. In other words, it is decided in favour of profit in the narrowest technical sense of the term. But even so, the throwing out of work of a staff of specially trained employes who can not afterwards be replaced except at inordinate expense is a material consideration exercising influence upon the decision; an influence precisely similar to that of the stoppage of the plant. If now the choice of alternatives were decided in the interest of profit in the fullest and largest sense of the term, it is clear that there would be much less plant shut down and much more "dumping" than there actually is. This is what would happen if the shareholders and the employes were identical persons; if the choice were decided in the interests of all those who are actually and humanly interested. It is because the power to decide such questions necessarily rests mainly in the hands of the capitalist owners, that the decision is usually made for the best advantage of technical profits and not for that of profit in the broad sense of total gain or benefit."

What has been written before 1905 remains true to-day, more so with the growing democratization of industries, except that "dumping" is being practiced now much more frequently than British shareholders were inclined to do a decade or two ago. An interesting illustration of the effect of reduced production on the accumulation of expenses on idle portion of a plant may be seen in Figures 28 and 29. Due to the reduced demand of a railroad securing another source of electric supply, the plant lost some load, thereby throwing a portion of the generating equipment into idleness and at the same time increasing the use of a portion of equipment kept for the pur-

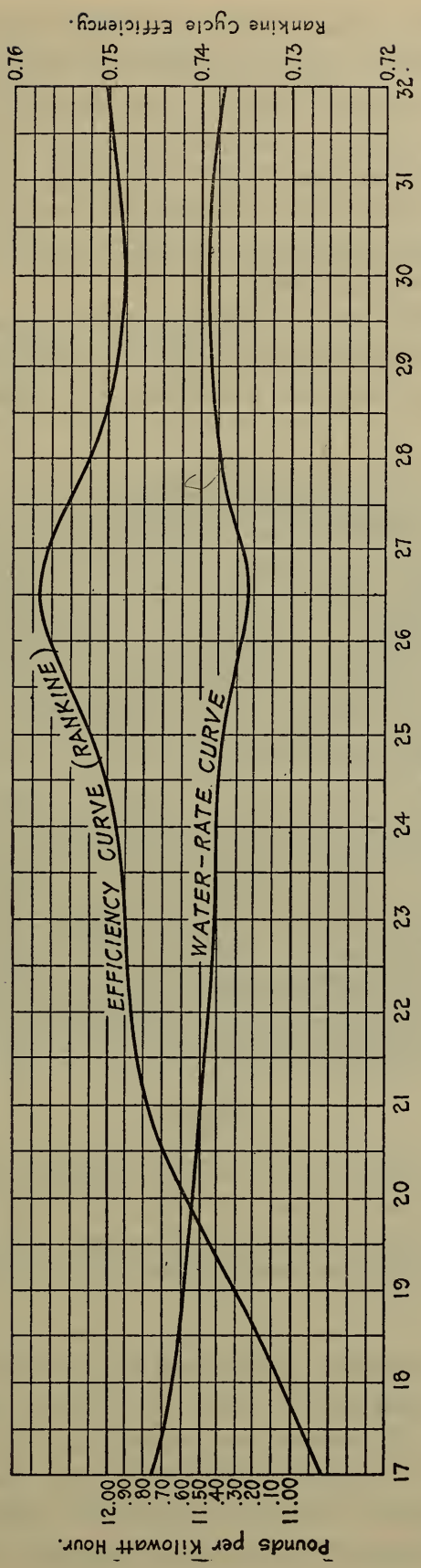


FIG. 26.—TEST CURVE OF A 30,000 KW. CROSS-COMPOUND TURBINE

pose of protection. The increase of total non-use cost appears to be $85,000.00 per year while the increase of expense for having spare protective equipment $46,800.00. One can readily picture the obvious advantages which could be derived by the plant and the community served by it if the sequence of charts in time were inverse, indicating a more extensive utilization of productive equipment and consequently useful application of capital invested and of labor and material worked into machinery.

Now, the danger of over-equipment lies not so much in the fact that the labor and material was spent for something for which there is no demand, nor even that the money idly invested claims an un-

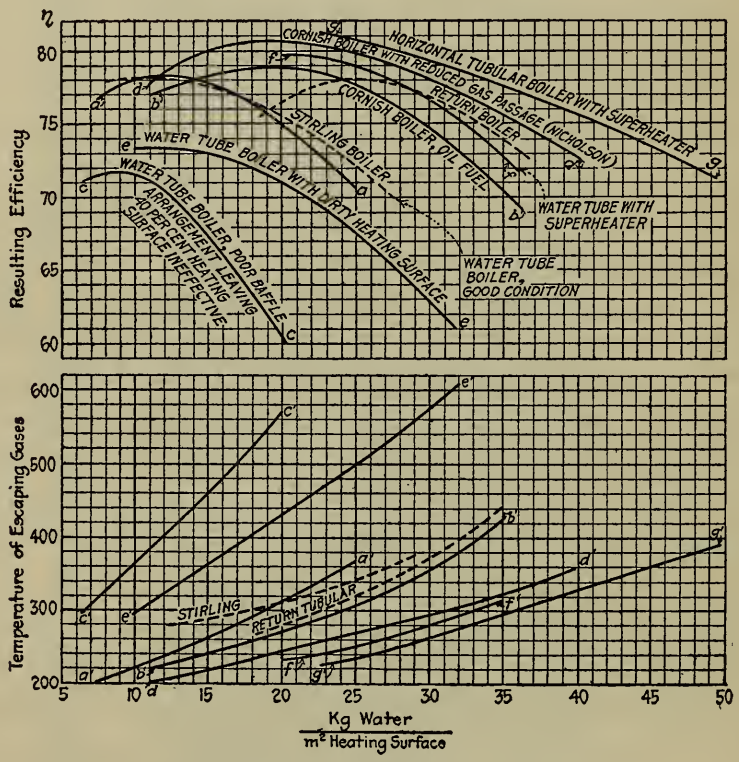


FIG. 27.—RECORD OF NINE DIFFERENT BOILER PERFORMANCES

Some of the tests here represented were made by the author and some by Prof. Grinevtzki of Moscow Institute of Technology. They do not represent the boiler performance under ideal conditions, but illustrate actual effects of diverse influential factors.

earned income (therefore compelling the consumers to pay something for nothing) but in the social evil of having productive capacity non-productive. *Idle productive capacity means in the last count want amid plenty.* If the production is less than the productive capacity, the product is sold for more than it could be if there were a larger output; higher prices overtax the local market at the same

time that only a part of the equipment is in use; only part of the workingmen find employment and total wages are thus reduced; and the domestic buying capacity is diminished. The conquest of foreign markets becomes indispensable, but since other industrial countries are similarly pressed for export trade, international competition ensues, culminated from time to time in wars. But even then, with this "Godsend" of war orders, the productive capacity of modern

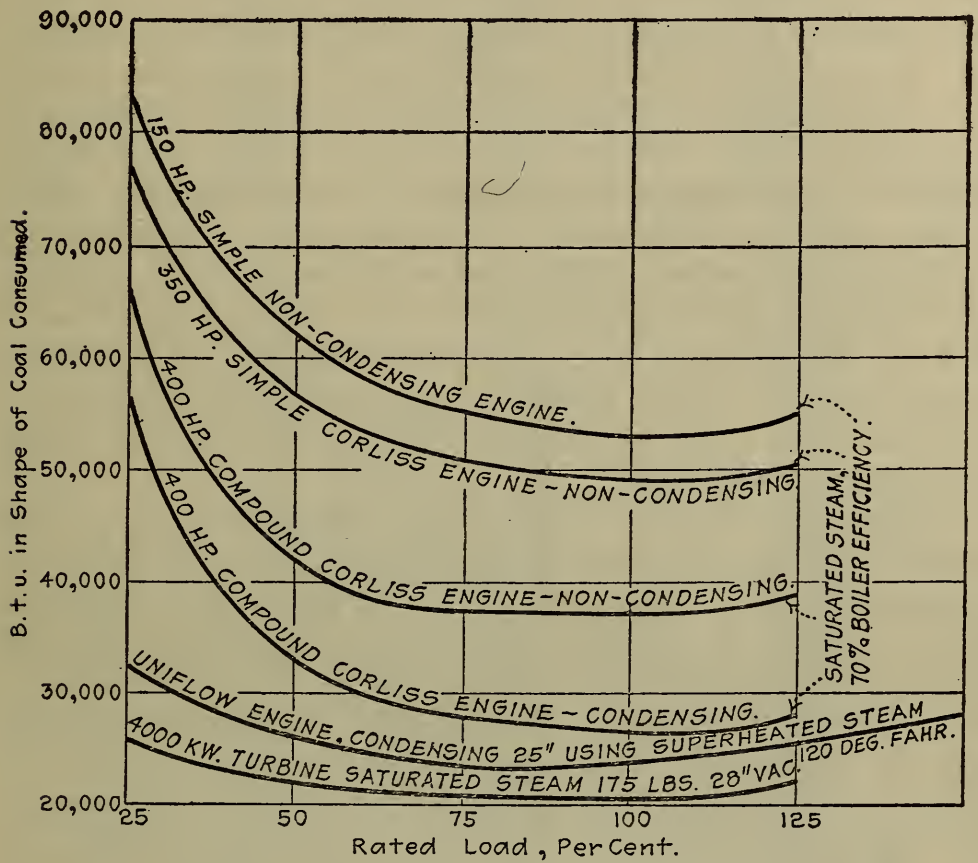


FIG. 27*A*.—HEAT INPUTS IN SIX TYPICAL CASES

Summary of tests of actual installations of widely varying characteristics for different per cent of rated load.

means of production was not fully utilized, since with the ranks of workmen depleted for armies a very large percentage of the population still did not take any part in the greatly increased output of the productive work of the rest of the workmen. During peace between the nations equally merciless wars are waged within nations when a large portion of productive machinery is held inoperative in order to keep the prices on products high and wages low. The conflict between labor and capital is thus bred and aggravated by this limited use of productive capacity. The experience of many

electric companies during the war just concluded substantiates the above facts if indeed they need any further illustration.

The power generating capacities of many public utility plants were overtaxed; a number of applicants were put on the waiting lists; government was asked to finance the enlargements of the power plants; the amount of coal consumed for power generation broke all previous records; and the amount of power consumed by industrial establishments was unprecedented. At the same time two millions of men capable of working were unavailable for industry and the nearly equal influx of immigrants has practically ceased. If, at the same time, an allowance is made for the labor consumed for production of more machinery for further production and if the amount of labor engaged in production of war articles not needed in peace time is next subtracted it will appear almost incredible what an insignificant portion of labor and machinery is really used for the satisfaction of the present scale of civil needs. At the same time we are told by various authorities that existing equipment is used not over half the regular working hours and the efficiency of its use is far below the possible mark by something like 50 per cent in most of the cases.

Taking again the power industry as a standard, though a large portion of power is generated outside the public utility stations, our immagination will be almost overtaxed if we consider what an enormous proportion of productive capacity is being withheld from use for the satisfaction of existing needs. To put it in other words—the equipment, the investments in the productive capacity have been made for the purpose of *earning interest,* not with the view of *increasing productivity.* The machinery, of course, was to be utilized in a measure but that was not the object, merely an incident. An economist puts it: "The business man's place in the economy of nature is to 'make money,' not to produce goods. The production of goods is a mechanical process, incidental to the making of money, whereas the making of money is a pecuniary operation, carried on by bargain and sale, not by mechanical appliances and powers. The business men make use of the mechanical appliances and powers of the industrial system, but they make a pecuniary use of them. And in point of fact the less use a business man can make of the mechanical appliances and powers under his charge, and the smaller a product he can contrive to turn out for a given return in terms of price, the better it suits his purpose. The highest achievement in business was the nearest approach to getting something for nothing. What any given business concern gains must come out of the total output

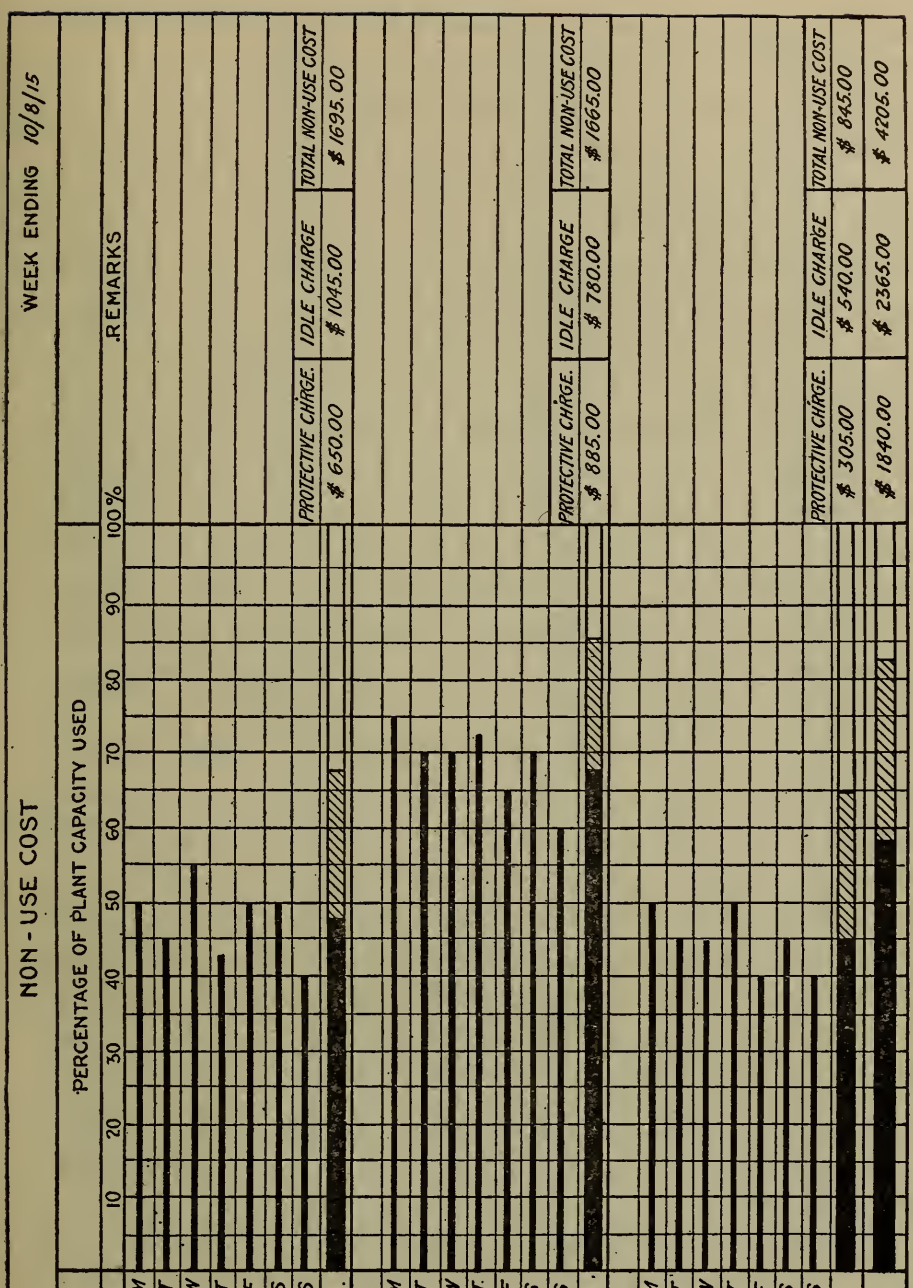

NON-USE COST
WEEK ENDING 10/8/15
PERCENTAGE OF PLANT CAPACITY USED
10 20 30 40 50 60 70 80 90 100%
REMARKS
M T W T F S S
BOILER PLANT TOTAL
PROTECTIVE CHRGE. $ 650.00
IDLE CHARGE $ 1045.00
TOTAL NON-USE COST $ 1695.00
TURBINE ROOM TOTAL
PROTECTIVE CHRGE. $ 885.00
IDLE CHARGE $ 780.00
TOTAL NON-USE COST $ 1665.00
ELECTRIC PLANT TOTAL
PROTECTIVE CHRGE. $ 305.00
IDLE CHARGE $ 540.00
TOTAL NON-USE COST $ 845.00
ENTIRE PLANT TOTAL
PROTECTIVE CHRGE. $ 1840.00
IDLE CHARGE $ 2365.00
TOTAL NON-USE COST $ 4205.00
LEGEND:- Capacity Used Protective Capacity Idle Capacity

FIG. 28.—EXPENSES OF EXCESSIVE PLANT EQUIPMENT

Allowing 20% of spare capacity of equipment for incidentals and unusual peak-protection (shaded bars) over and above maximum daily load we see that 15% excessive capacity of a plant and 33% excess in boiler installation results in $4200.00 weekly unabsorbed overhead charges on this electric railroad plant.

of productive industry, of course; and to that extent any given business concern has an interest in the continued production of goods. But the less any given business concern can contrive to

give for what it gets, the more profitable its own traffic will be. Business success means 'getting the best of the bargain.'"

Or, quoting a speaker at the annual banquet of the alumni of Stevens Institute of Technology,[55] "If you went to a bank before the war—great things have happened since the war—in London or Paris or New York, the question they cared to consider was: 'Can you show us how we can derive income for investors out of what you propose?' The mind was riveted to the investor's point of view, that is to say, riveted to the point of view of the people who live on their income, the point of view of leisure and idleness. I am not saying we don't all want to be idle a considerable part of the time; but I submit it isn't reasonable that the work of the world should be done in my idle moods or from the point of view of my idle moods. It isn't safe either for my investments, if I have any—not in the long run. If a bank thinks only of the investor and doesn't think of the improvement of the working plant upon which all securities rest, sooner or later the working plant clogs up and grinds its own cogs and the investments are forfeit.

"It is largely because of the false practice of the financial communities of London, Paris, and New York, that we have a grave social problem. The great bankers are all conscientious and well-meaning men, so far as I know. But they have in the past been indoor men. They have lacked the outdoors point of view. They have absorbed their minds in the figures in a book, without an adequate conception of the external world. Here and there there have been exceptions; here and there somebody did think of the practical arts, but in the main, they didn't care for technology or for building of cities. They did not look at things from the point of view of the entrepreneur or the engineer. There wasn't any engineer in the bank."

Since this was said and written, many things have begun to change under the influence of the lessons taught by the war. Some banking institutions begin to realize that investment for the sake of investment is neither profitable nor safe so long as the economic structure is getting top-heavy from piled over-head charges on idle equipment. Moreover, they begin to seek the advice of an uninterested engineer as to what is a productive enterprise for they begin to realize that the new field of credit is being opened on the basis of *what the plant or man can do,* instead of the old criterion of what it can be bought or sold for. The valuation of industrial methods gains its recognition over valuation of industrial property[23] while but a few years ago the author's paper on the subject fell on the

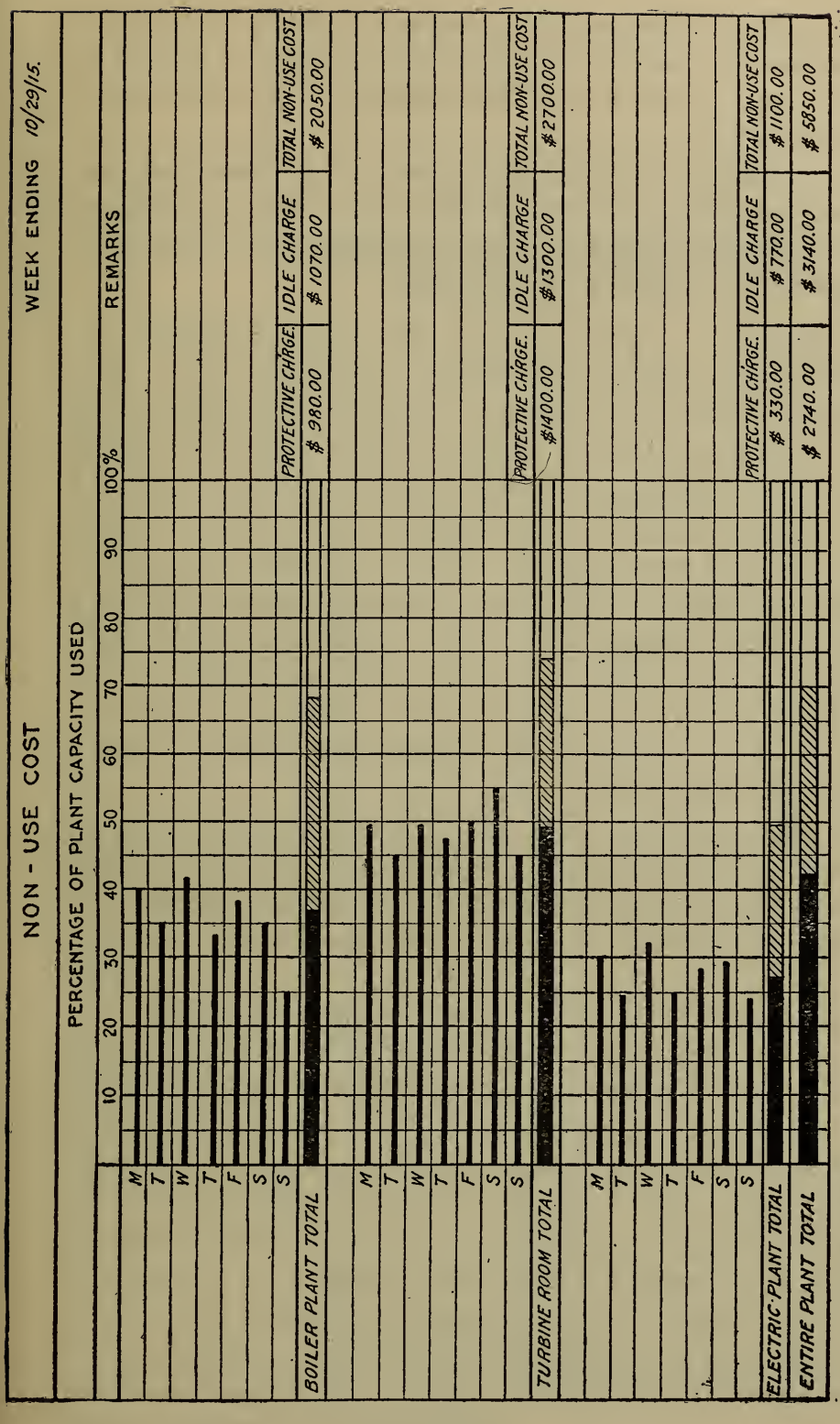

NON - USE COST
WEEK ENDING 10/29/15.
PERCENTAGE OF PLANT CAPACITY USED
10 20 30 40 50 60 70 80 90 100%
REMARKS
M T W T F S S
BOILER PLANT TOTAL
PROTECTIVE CHARGE. $ 980.00
IDLE CHARGE $ 1070.00
TOTAL NON-USE COST $ 2050.00
TURBINE ROOM TOTAL
PROTECTIVE CHARGE. $1400.00
IDLE CHARGE $1300.00
TOTAL NON-USE COST $2700.00
ELECTRIC PLANT TOTAL
PROTECTIVE CHARGE. $ 330.00
IDLE CHARGE $ 770.00
TOTAL NON-USE COST $1100.00
ENTIRE PLANT TOTAL
PROTECTIVE CHARGE. $ 2740.00
IDLE CHARGE $ 3140.00
TOTAL NON-USE COST $ 5850.00
LEGEND:- Capacity Used Protective Capacity Idle Capacity

FIG. 29.—INCREASED NON-USE EXPENSES WITH REDUCED LOAD

The load of the same plant two weeks after was materially relieved by parallel operation with another plant. Character of service becoming chiefly to take care of peaks, protective capacity allowance was increased to over 25%, yet the idle portion of plant was nearly 30%. This increased cost of idleness by $645.00 weekly or about $35,000.00 annually, besides a direct increase of operating cost per kw. hr. due to small load on large plant.

deaf ears of even the most progressive ones. On the other side of the Atlantic a similar reshaping of ideas is taking place. The British Ministry of Reconstruction clearly sees and does not hesitate to

state[56] that "the old standards are definitely changed, as was the inevitable outcome of a war to make democracy safe. A man is judged to-day not by the size of his banking account but by the record of his deeds."

To gain the correct conception of the value of the plant both for investors and the public, one should know more than its physical properties—a valuation should be made of the mode of its use, and that is primarily the method of its operation.

Chapter IV

MASTERING MATERIALS

APPROACHING the second group of questions involved in the problem of mastering power production; namely, those relating to materials, supplies, and other technical requisites, it would be fitting to begin by drawing a clear distinction between materials as marketable commodities and materials as products of socially necessary labor. In the former aspect, materials are subject to market speculations and have a merely pecuniary value; their loss or waste or misuse is measured in their money equivalent. From the second standpoint any material, whether so called natural resources or fabricated supplies and parts, represents certain amount of human labor-power, and waste or misuse of materials thus regarded is a loss of human life. Loss of money equivalent of materials may be recompensed through some other financial operation; loss of material itself is an irretrievable loss of time and human energy spent in its production even if the residue of misused material may be again, by application of more labor, worked into some useful form.

A financier, a business man, concerns himself solely with the first meaning of materials and from the business view materials are only forms in which portion of variable capital engaged in production appears. It is the business of an engineer to reckon materials in their true nature, that is as to their peculiar fitness for the production process involved. The social meaning of materials does not receive its significance so long as proper use is made of it, which means that the amount of labor-power worked into it finds its expression in the ultimate result to which it was applied, being diminished only in such a degree as the existing state of art and the limitations of the nature of the process makes it unavoidable.

While it is common to measure any kind of useless expenditures of time, materials and efforts in terms of money equivalent that were spent without producing material results,

the true social meaning of waste is at once deeper and broader than mere loss of money. In fact one conception does not necessarily cover the other. Take for example a steam-electric plant that ordinarily consumes one-third more coal per kilowatt hour than it would if more knowledge were displayed and more care exercised. This means that its coal bill is one-third higher than it might be, thus a corresponding amount of money is apparently wasted. Yet the financial interests of the investors are protected insofar as they recover this loss of uselessly destroyed fuel by including this amount of money into the price of electricity sold. Public utility commissions either have their hands tied or are otherwise incapable of determining how much coal should be used and consequently rates are approved when based on high consumption of coal per kilowatt hour whereas a reasonable figure would be much smaller than commonly found. The community consuming this electricity pays therefore back to the owners what they overspent on coal item. The net result is, of course, that the money representing the value of wasted coal keeps on circulating and the community, so overcharged for electricity, also pays wages to coal miners and profit to operators and railroads on the amount of unnecessary coal, which was burned without producing and serviceable energy.

In fact it might well be assumed that the electric company collecting in this fashion a greater bulk of revenues than it would with smaller operating expenses, has a somewhat higher operating capital and consequently claims even at the same rate of interest, a greater bulk of profit. Furthermore, a situation may be elaborated in which the larger expenses (inflated by cost of waste) yielding revenues allowed by commissions being interpreted as an indication of growing business, this may further be capitalized as good will or some other intangible asset, and eventually covered by an issue of securities and thus ultimately bring further income. Study of various records of hearings held by different public utility commissions brings ample evidence of such practice, which incidentally, is being frequently referred to by speakers in the engineering societies as "penalty imposed on the community for tolerating inefficiency"; "price of waste and mismanagement paid by the country," etc.

While some economists may deny these terse charges by pointing out the increased money circulation resulting, the facts of the other side of the proposition remain, that the natural resources, through their misuse, are wasted and the work of an

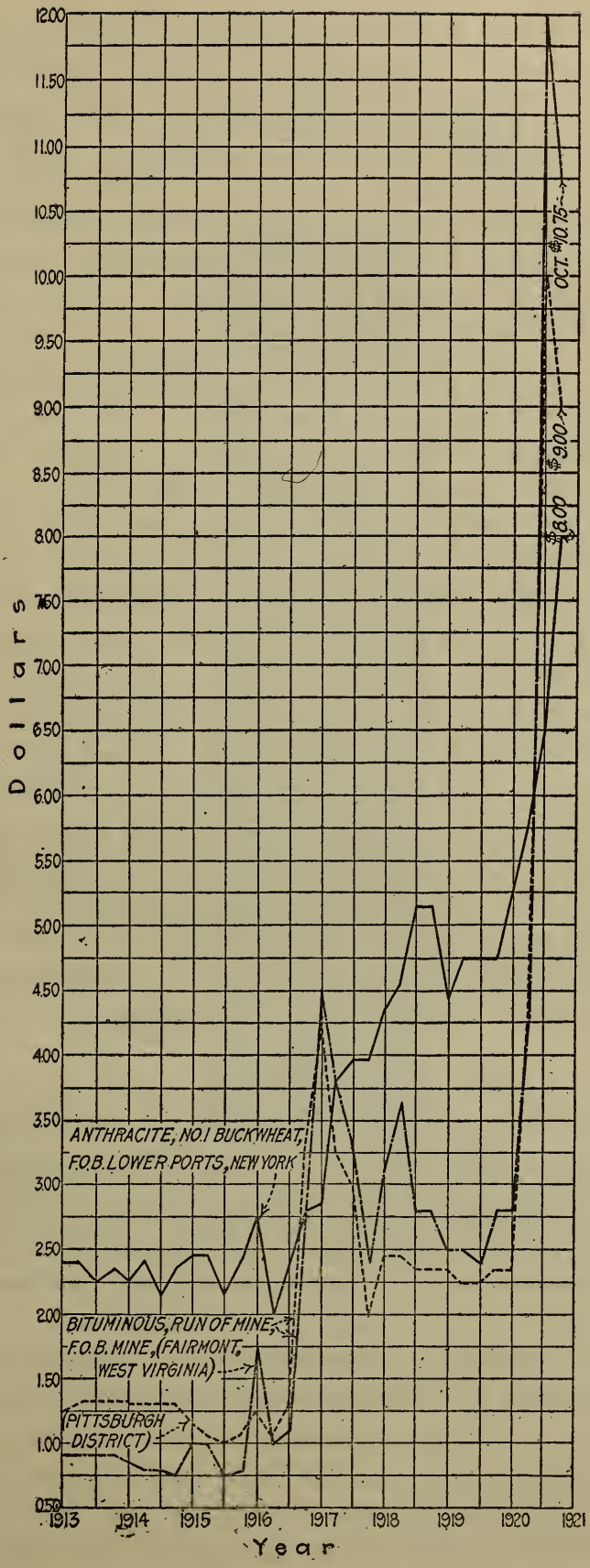


FIG. 30.—WHOLESALE PRICES OF REPRESENTATIVE COALS

endless chain of men is applied to produce something that serves no useful purpose. In other words, a certain amount of work is rendered unavailable for production of some much needed commodity or service. In the modern structure of the industrial community, with its closely correlated branches and fields of activity, specialization is so complex that an attempt to trace the effect of misuse of any specific material is well nigh impossible, except in the most general terms. A poor combustion of fuel in a furnace for instance, at once renders the work of a great number of men useless and unavoidable for other purposes, for coal represents labor of a long chain of men—to name but a few: lumbermen, teamsters, steel-mill workers, machinists, chemists, railroad men, engineers, clerks, miners, since the work of all these was absolutely indispensable for mining and delivering coal which was burned under the boiler without producing all possible steam. Moreover, the work of none of them would have been possible unless scientists, architects, cattle-men, shop-keepers, textile workers, tailors and what not had toiled so that others could do their part in this enormous working community of the modern state. From this standpoint any waste of coal or of any other material means that a certain amount of the work of all these numberless men, whose work intricately depends one upon the other, is rendered useless. This in turn means that the time they toiled to produce something that is thrown away, was not used to anybody's good. As this waste is considerable, the sum total of the portions of time that all the men worked to produce something that is wasted is very large.

In order to grasp and visualize the extent of present day losses of coal alone in our power industry we must consider that out of upward of 400,000,000 tons of coal used annually for power production at something like 75,000,000 tons are used needlessly and could be saved by scientifically adjusted methods of mastering power production. The diagram Figure 30 represents the fluctuations and general trend of wholesale coal prices as reported in the *Journal of Commerce and Finance,* published by the National Bank of Commerce in New York. At an average price of $5 per ton this reckless dissipation of fuel in power production cost to the nation $375,000,000 annually, not counting in the expenses of transportation, handling, etc. To avoid this waste of materials no new equipment is needed, no radical change in

the conduct of industry is involved—it calls merely to practicing principles advocated in this volume.

Turning now to the social significance of this material waste from the viewpoint of possibilities of putting power production on a new basis—coupling it with the multiple production of

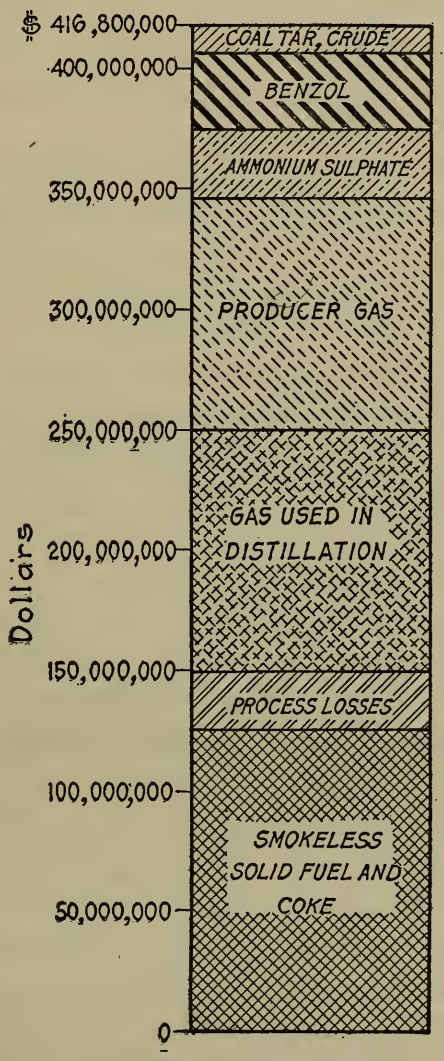


FIG. 31.—RELATIVE VALUES OF COAL BY-PRODUCTS

Approximate relative commodity values of by-products of low temperature distillation of coal lost when raw coal is used as fuel. Based on recovery from $\frac{1}{10}$ of normal annual consumption of raw soft coal. Prices subject to large fluctuations.

various by-products of coal and thus deriving, besides more power, a large quantity of other useful and badly needed commodities, we must consider the following facts: the mining of the minimum quantity of coal that may be readily saved, say 75,000,000 tons annually, employs uselessly the labor of about 100,000 coal miners, and the haulage of 5,000,000 car-miles, in addition

to a large amount of other labor and material required in connection with the mining, transportation and building and maintenance of equipment employed in this unproductive output.

The further great values to the nation which go up in smoke with this wanton waste are seen from a computation of all the useful elements that are extractable from bituminous coal: in one ton of bituminous coal, if split by distillation, its multiple products would have had a collective value of at least $16, or about eight billion dollars per year.

In terms of cash, the price value of the minimum of the 50,000,000 tons of coal wasted yearly in power production alone—not taking into account the large tonnage wasted in connection with other uses—had the value of the multiple products of this coal over $800,000,000, probably $1,200,000,000.

In terms of social value, the same coal wastage represents a loss of about 35,000,000 tons of smokeless fuel or coke, 500,000 tons of ammonium sulphate, 100,000,000 gallons of benzol, 400,000,000 gallons of tar. Transferring these amounts into other values, we find that the nitrogen contained in 500,000 tons of ammonium sulphate is capable of raising the production of wheat by 43,316,000 bushels, based on 115 pounds of nitrogen to the acre. Benzol is superior to gasoline and the above amount is valued at about $30,000,000, capable of accomplishing an enormous amount of mileage of trucking and traveling. The 400,000,000 gallons of tar would make possible the extension of rural highways, and keep the present roads in good condition. The above examples concern only the primary products while other chemicals, drugs, dyestuffs, etc., could be extracted.

The gravity of this situation and public responsibility in the matter will only be met when the facts become generally known and appreciated. Already a small number of progressive concerns, employing expert advice and organizing their power production along more intelligent lines, are eliminating this wanton waste.

Figure 31 represents graphically the values of primary by-products of 35,000,000 tons of coal, i e., if less than half of coal now wasted could be subject to this slow destructive distillation. In this case the value added by manufacturing of raw coal is $416,800,000 per year even if a ton of coal is priced at $5 per ton while the by-product prices are as low as they were in 1917, i. e., ammonium sulphate 3 cents per pound, benzol 28 cents per gallon, tar at 3 cents per gallon, and gas at 90 cents per 1,000 cubic feet.

In procuring materials for industrial purposes and more specifically those needed in the manufacture of power, the criterions applied in selection are necessarily determined by the light in which the materials are regarded. As in the case of the selection of equipment, whenever the financier or business man assumes the authority of deciding the question unguided by knowledge of technical peculiarities of the processes involved and the specific requirement of the materials used, he almost invariably displays more than mere ignorance for, by the force of habit and training in a different field, he judges from the viewpoint of a bargain, that is, he usually displays an inclination to buy largest bulk for cheapest price. Another customary fault of narrow business judgment is that choice of materials is made without due regard to broader economic considerations.

We have come to inherit from the historical development of our economic structure the idea that the privilege of control of purchases is vested with owners of money. With the highly developed technique of industrial processes and accompanying complexity of requirements for materials and supplies used, the insistence of business directors that they have a say on how their money should be spent in the procurement of materials, is becoming more and more discretionary, arbitrary and at times ridiculous, not to say that such direction may be wise only in cases when the business head of the concern and technical expert is one and the same person. That the unsuitable or ill-adapted materials cause a loss is seldom apparent to a business head whose judgment of efficiency of an undertaking is based on the accountant's reports or trial balances perhaps elucidated at times by statements of bills payable for materials. The effect of unsuitable materials on the thermal or other efficiency of the process in question, on cost of maintenance, on hardships imposed without returning benefits on the employees and even on the unit cost of production, is often obscure to men whose skill consists in the ability to buy cheap and sell dear, not in producing efficiently, in keeping up plants in best operating conditions, and in relieving the men from all unnecessary strain as well as in eliminating every possible source of waste.

Purchases

The gap between the control of finances and the control of production grows wider with the development of technique and inconsistency of directing purchases merely from the standpoint

of "price per" has forced the delegation of a portion of this authority to especially appointed purchasing agents or departments. Nevertheless the fundamental inconsistency often remains intact inasmuch as even these purchasing agents often have to report and receive their orders from the business officers and not from the production experts. The gap of late is becoming narrower, both through adoption of standard specifications worked out by specialists, and supposed to direct the buyers and through a measure of latitude given to the heads of productive departments to "recommend" or even "specify" the qualifications of materials wanted. As a rule this practice of co-operation and engineering direction produces vastly more satisfactory results than the former custom of plenipotentiary rule of purchasing agents yet, in cases of some special departments, particularly so-called auxiliary departments, such as factory power plants are, it is still the custom that coal be purchased without the knowledge of the plant engineer; the question of what kind and grade will best serve his purpose being often decided by discussion between a banker, a sales manager, and a superintendent of a manufacturing department. It is entirely possible, in such and similar cases, that the plant engineer, who was hired probably chiefly because he did not ask high wages, does not himself know what fuel will best suit his furnaces, and he knows even less where and when the fuel is obtainable, so that an outside specialist's investigation and advice is gradually being more frequently resorted to whenever the small volume of business does not warrant the permanent employment of an expert.

Some aggressive selling organizations not infrequently take advantage of the situation which arises whenever the purchaser has no one on whose wisdom in selection he may rely; the salesman in such cases brings in his own "expert engineer," who has little difficulty to represent the goods or the services of his employer in a most convincing way to buyers confessedly unsophisticated in technical matters. At times this practice assumes especially tempting forms, as when the closing of a contract is stimulated by an offer of "free" service or at a "nominal charge." Sale of coal on that plan at one time gained popularity though gradually it is falling into disrepute as might be anticipated, for during a competitive trial of a coal offered under the direction of coal company's expert, results could be easily obtained that are far better than the boiler room force could

duplicate unaided or, especially, maintain afterwards in every day operation. Likewise purchase of equipment, supplies and apparatus according to similar plans is not always satisfactory to the users partly because they permit themselves to be talked into a belief that its use will result in a real economy merely on the virtue of machine itself irrespective of the mode of its use. Thus often the disappointment is well-deserved and the sales engineers must be exonerated from great portion of responsibility for

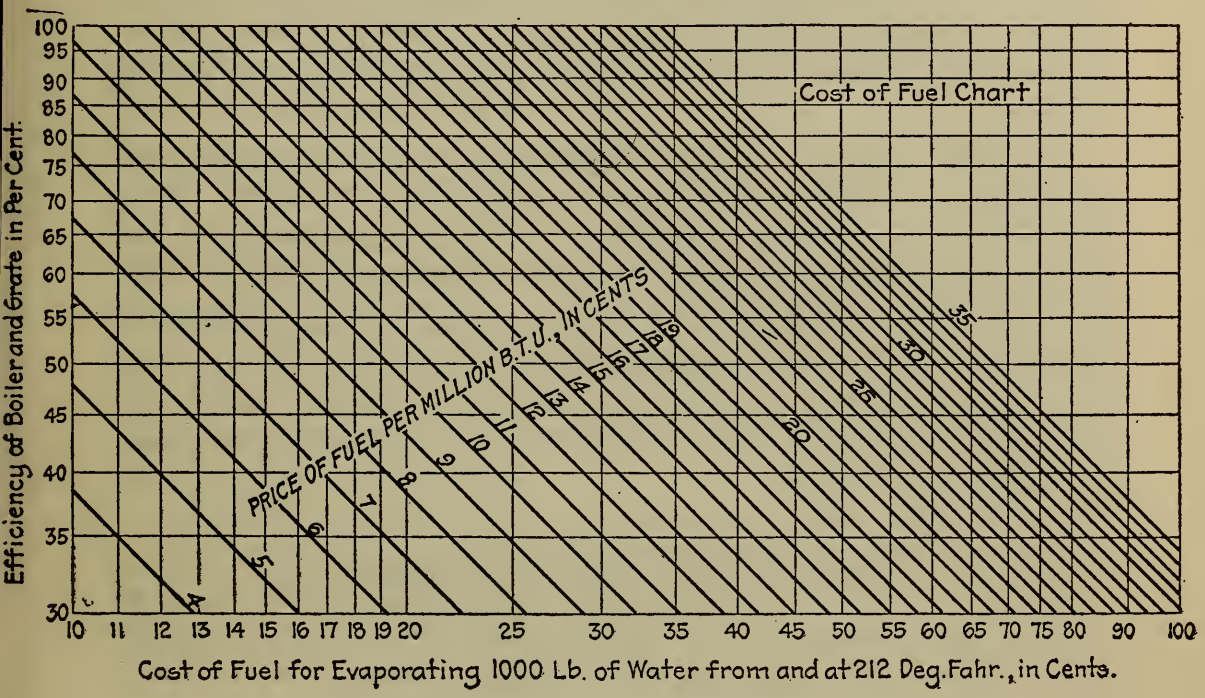

Cost of Fuel Chart
Efficiency of Boiler and Grate in Per Cent.
PRICE OF FUEL PER MILLION B.T.U. IN CENTS
Cost of Fuel for Evaporating 1000 Lb. of Water from and at 212 Deg. Fahr., in Cents.

FIG. 32.—COST OF FUEL PER 1000 LBS. OF STEAM

Diagram for computing the cost of fuel used for generation of 1000 lbs. of steam at various boiler efficiencies based on different prices paid per million B.t.u. in shape of fuel.

exaggerating the merits of their goods. The reason that the promised results are not actually obtained is the improper method of use. A manufacturer of a CO_2 recorder had shown to a writer a complaint from one user of his apparatus who blamed the recorder for not improving the efficiency of combustion!

The authority to make the purchase involves responsibility for the suitability of materials or article bought for a certain purpose. It is as much a waste of public funds and labor to install in the plant something that does not serve its purpose as it is to destroy the corresponding value of labor or its product. In other words, possession of plant and materials involves a social

obligation to see to it that the plant is put to the best possible use. If the knowledge available is insufficient to attain the best results possible, additional knowledge should be secured.

The World War has taught us that it was not the ability to buy, but to produce that insured success. In war the better mastering of materials secures victory; in industrial competition the waster is the loser; in social progress that community attains the highest standard, which gets most out of its material resources. To accomplish this task, it is necessary to eliminate all guess, uncertainty, favoritism, and waste; a definite, predetermined, impartial and efficient use of materials is a *conditio sine qua non* of success.

As long, however, as our industries and public utilities are controlled by men whose vision is limited to a narrow circle of private gains, small wonder that the representatives of the people gradually extend governmental control over them. The feeling of distrust is spreading toward managerial methods based upon obsolete ideals and fostered by the conditions of the past and the right to mismanage socially necessary production and transportation or to waste the Nation's natural resources, is being gradually taken away.

Prices vs. Use Value of Materials

The most conspicuous of these harmful inheritances from the age of mercantile capital is the habit of judging the value of services and of goods alike from their market price. Men who are traders by profession and speculators by temperament, are accustomed to accumulate wealth by buying cheap goods and reselling them for what the traffic will stand. The process is thus to transform money into commodity and exchange it later for a larger sum of money. The buying of certain materials needed in the process of power production is done with the intention of realizing larger returns when the raw material reappears in the new form of a marketable commodity; namely, energy. As a mere bookkeeping proposition, it looks as if the lowest price paid for these materials is capable of augmenting the profit, or the difference between the cost-price and the market-value of the power. A technically unsophisticated purchasing agent, or an official dictating the policy of a concern, is often trapped in the tenets of this fallacy. While it might be true in a case of direct reselling of merchandise, that the low purhase price

leaves a larger margin for profit, in the case of materials entering into a process of power production, the price of the materials per ton, or pound or per foot, etc., has little or no bearing on the cost of ultimate product-power. *The only reliable criterion of the price of material is its effect on the unit cost of ultimate product.* Thus nothing but scientifically conducted experimentation under service conditions and carried out by a trained engineering investigator can establish the fact as to *what article is cheapest to use as opposed to what is cheapest to buy.*

The purchasing agent should be directed only by properly established engineering standards; to permit of their timely revision, he should report to the engineers setting the standards any fluctuations in the purchase prices, deliveries, specifications, etc., of all catalogued materials. It is hardly necessary to illustrate this assertion by examples only too well known to operating engineers, but often foreign to financial directors. A cheap grade of lubricants or anti-friction metals, of boiler tubes or fitting, etc., does not only enormously increase the maintenance expense but seriously jeopardizes the safety of men and property and, above all, frequently causes interruptions in the service with all their far-reaching consequences.

Of all the materials used in the steam power plants the fuel for the reason that it is by far the largest item in the operating expenses, attracts the most attention to the problem of its selection.

Coal As An Example

The most primitive method of selecting coal is the comparison of prices per ton. This is occasionally modified by legal regulations, security of deliveries, terms offered in the contract, and similar commercial considerations. Thus in New York City the use of anthracite has been favored and even made obligatory so long as law-makers believed bituminous coal to be smoky; in Maine, Pocahontas and New River coals were in vogue, even in unsuitable furnaces, since little ash may be hauled over the long route; in Pennsylvania, sometimes unsuitable coal is brought from far away mines because of a lower bid per ton on a long-term contract.

In the first decade of this century the methods of buying bituminous coal on a heat value basis became fashionable. The more conspicuous of these methods were those of the United States Geological Survey, the Panama Railroad Company, the

Interborough Rapid Transit, City of New York (See Appendix 2) and the Celluloid Company. It was as much a step in the

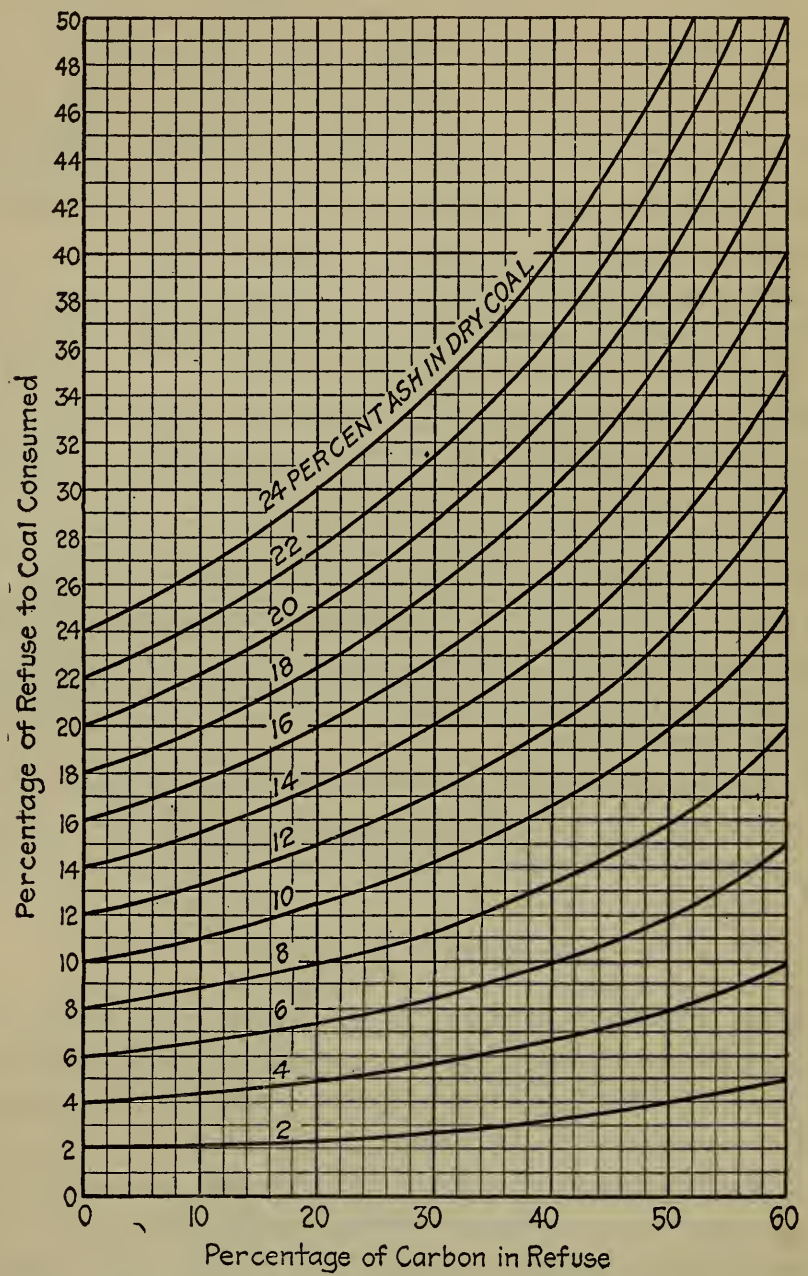


FIG. 33.—RELATION BETWEEN ASH CONTENT AND FURNACE REFUSE

Diagram for approximate determination of furnace refuse to be expected from coals of different ash contents with various percentages of loss of combustible in refuse; it may similarly serve for estimation of percentage of carbon lost in refuse from known amount of refuse and ash content in coal.

proper direction as the selection of food according to its caloric value though the parallel goes still further. A dietician knows that foods of equal heat value have different coefficients of

digestibility; moreover, there are proteins that stop animal growth while others stimulate it. While again, some nourishing foods are not palatable. Similarly it is not enough to know that a million B. t. u.'s cost so much and the price may be further adjusted according to the variation from the "normal" proximate analysis. The fitness of the coal for the furnace, service, local conditions, etc., must be carefully investigated before it may be said whether the coal containing the most heat units for a penny is the cheapest.

Unquestionably the great merit of this method of payment for coal on the heat value basis lies in the fact that *it calls for some exact knowledge.* The knowledge of the quality of every delivery on the part of the buyer stimulates the seller to exercise care in the preparation of the order so as to avoid penalties; eventually the knowledge of the effect of the composition of coal on the ultimate results obtained, helps the user to adjust specifications to requirements or *vice versa* to modify the methods of use or equipment to the character of fuel available. Neither of these adjustments could be made without a knowledge of the characteristics of the coal. Moreover, the contents of the coal, the behavior of the volatile matter in the furnace, peculiarities of ash, etc., must be known *before* the coal is used, since variations in the properties of coal call for different rates of air supply in the furnace in order to properly burn the coal; shorter or longer periods between leveling or cleaning fires, different thicknesses of fuel bed, etc., must be standardized if high efficiency is to be attained.

The importance of the information obtained from the coal laboratory could hardly be emphasized enough, and a modest investment for its simple equipment is perhaps the best investment after the boiler room instruments, from the viewpoint of economy, as well as of conservation of natural resources. The employment of an outside laboratory, however, is warranted only in a case when the analysis returns may be made available before the coal is used in the boiler room. The knowledge of what kind of coal *has been* burned is no consolation if the methods of its utilization were guessed wrong and resulted in an excessive waste.

Engineering Direction of Purchases

To further illustrate the nature and the extent of the important role that an engineer should play in directing purchases

of materials and supplies, we may again refer to our example of coal. Engineering furnishes scientific means for determining with precision the measure of waste and of preventable losses in productive processes. These wastes and losses are large in the ordinary process of power generation. In this process the engineer has to consider primarily three stages:

1 The purchase of fuel, including receiving, storing, and handling. This is the transformation of money into potential thermo-chemical energy.

2 The combustion of the fuel under the boilers. This is the transformation of potential thermo-chemical energy of solid or liquid fuel into the gases in the furnace.

3 The utilization of the heat generated in the furnace for the evaporation of water in the boiler. This is the transformation of the heat of the gases into the volume energy of steam.

Figure 32 illustrates the correlation of these three factors: price, efficiency, and cost.

The first of these stages, the purchase of fuel, is usually characterized by great inefficiency, although it is true that it may be profitable to tolerate low efficiency if the cost of the product is low. The efficiency of a beam engine is much lower than that of a triple-expansion condensing engine, but sometimes the continued use of the former is commercially more economical. Analogous conditions may be observed in burning fuels of varying grades and prices in different types of furnace.

The prices at which some kinds of coal are sold are not proportionate to their thermo-chemical value. In other words, though in the cheaper kinds of coal there are fewer B. t. u. to the pound, yet one cent expended for such coals buys more heat. The possible commercial advantage from the use of these cheaper and poorer grades of fuel (screenings, breeze, culm) is, however, diminished by the increased cost of maintenance and heavier depreciation of the special apparatus which are necessary to enable us to utilize the maximum heat units obtainable from this fuel. It is therefore sometimes more profitable to use more expensive fuels, which can be satisfactorily utilized without additional expense for apparatus. Finally, cases are never met with in practice, where the resultant efficiency could not be increased by a more complete utilization of the fuel in the furnace, though there are many cases where this source of poten-

tial saving is negligible in comparison with the large economy obtainable by changing the coal specifications.

For our purpose, that is, the determination of the efficiency of coal purchase, three steps must be examined; that is, we must find first the *efficiency of payment,* that is whether the price is reasonable and how it compares with other offers; for this efficiency we may use the symbol E_m. Second, *efficiency of gastification,* that is, whether all that is combustible in the given fuel may be made available; for this we may use the symbol E_g. Third, *efficiency of heat utilization,* that is, whether the gases are thoroughly consumed and whether they deliver all their heat, or whether some of them are incompletely burned or are carrying away heat which might be utilized under attainable conditions; for this we may use the symbol E_t. These financial, chemical and thermodynamic factors of the total resultant efficiency of fuel, (E_r) converted into decimals, may be expressed in an equation which is universal for all kinds of fuel under all conditions:

$$E_r = E_m \times E_g \times E_t$$

In each of the three primary stages we have just been considering we can differentiate minor or secondary stages, standing to one another sometimes in the relation of dependent sequence, sometimes in simple correlation; these should be analyzed in conjunction with their corresponding primary stages. Thus, both theoretically and practically, nine typical variations are possible in the underlying conditions that affect the resultant commercial efficiency of the fuel —that make it possible to increase this efficiency by proper selection, purchase and utilization of fuel.

In recent years we have often heard the statement that "coal should be bought on a basis of the result it will give; that is, on the basis of thermal units." [67] This statement is true only as to the first part; the purchase of coal, like any other purchase, should depend on the purpose to be achieved, and it should be remembered, of course, that the results obtained depend upon the adaptability of the fuel, chemically and physically, to the furnace in which it is to be burned. It is well-known that certain coals are especially suited for certain purposes, and it is not necessarily true that the coal highest in B. t. u. will be the best for our special purpose, even though it be completely burned. For instance, coals high in volatile matter are the most difficult to burn efficiently, although they are high in B. t. u. Furthermore, coals having nearly the same percentage of volatile matter may have different heating powers on

account of the presence of heavy hydrocarbons, or such volatiles which are not combustible at all.

It is not necessary at this time to go deeply into the peculiar art of establishing standards. For illustration only, let us assume that 1,000,000 B. t. u. in steaming coal could be bought for 5 cents, while the actual price paid for two kinds of steam coal offered to a certain plant are 6 cents for 1,000,000 B. t. u. in small-sized anthracite, and 8 cents for the same potential thermal energy in bituminous coal; then the financial efficiency in these two instances will be 83.3 per cent and 62.5 per cent, respectively.

Our second step will be to determine the efficiency of gasification of the coal we are considering. In other words, we must apply exact methods of calculation in order to determine the ratio of energy utilized to energy available, this being the ratio to which we have given the title efficiency of gasification. Let us assume again that under the conditions of our special case the coal purchasable at 6 cents per 1,000,000 B. t. u. cannot be completely burned, but leaves on the grates and in the ash pit 38 per cent of unconsumed refuse. This coal shows by analysis 18 per cent of ash. The 38 pounds of unconsumed refuse, therefore, which is left by each 100 pounds of coal, contains but 18 pounds of absolutely non-combustible ash, the remaining 20 pounds (or 52.6 per cent of the entire refuse left) being combustible, left unconsumed. The efficiency of this process can be easily computed. 100 pounds of dry coal consists of 18 pounds ash and 82 pounds combustible, out of which 82 pounds we are wasting, as we have already seen, 20 pounds. The remainder, 62 pounds, is therefore the quantity of combustible gasified. The efficiency, therefore will be:

$$E_g = \frac{\text{Combustible used}}{\text{Combustible available}} = \frac{62}{82} = 0.756$$

In other words; the efficiency of our process of gasification is 75.6 per cent in the case of the coal costing 6 cents for 1,000,000 B. t. u. Figures 33 and 34 show in graphic form the relation between the combustion of coals, the percentage of refuse to coal used, the percentage of combustible in the refuse, and the efficiency of coal consumption.

Let us now assume further that the bituminous coal already referred to, costing 8 cents per 1,000,000 B. t. u., shows an efficiency of combustion as high as 96.6 per cent under the same conditions as the anthracite just considered. And let us also assume that the efficiency of the third stage (the utilization of

the products of combustion, or, in other words, the transformation of the heat energy of the gases into volume energy of steam), is 64.1 per cent in the case of bituminous coal. The efficiency of this third stage is determined by actual steaming or evaporative test, and is figured in accordance with the for-

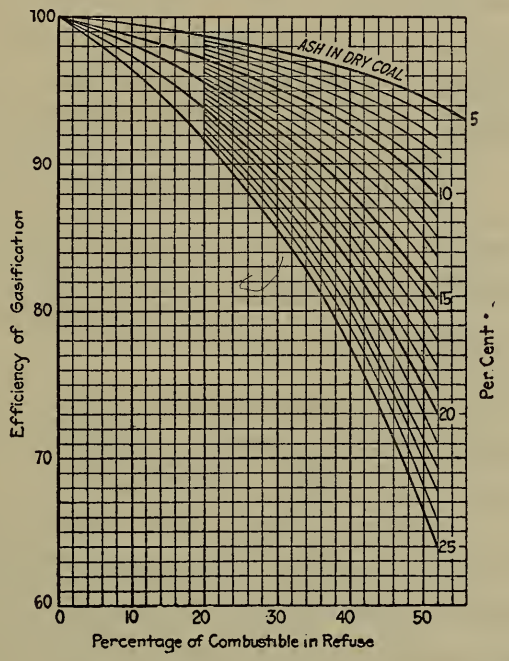


FIG. 34.—RELATION OF EFFICIENCY OF GASIFICATION AND LOSSES OF COMBUSTIBLE IN REFUSE

If no combustible is to be found in furnace refuse, it would mean that 100% of solid fuel was gasified. Relation between ash and dry coal and combustible in the furnace refuse indicates the efficiency of gasification.

mula given in the code, for conducting boiler trials of The American Society of Mehanical Engineers.

$$E_t = \frac{\text{Heat absorbed per pound of combustible}}{\text{Thermal value of one pound of combustible}}$$

We have now all the data necessary for determining which coal is the more efficient. A comparison of the resultant efficiencies of the two kinds of coal shows:

E_r (anthracite) $= (83.3 \times 75.6 \times 64.1) + 10{,}000 = 40.367$ per cent.

E_r (bituminous) $= (62.5 \times 96.6 \times 71.2) + 10{,}000 = 42.987$ per cent.

Now we can see that the use of the coal costing most per ton and per unit is in this particular case about 6 per cent more economical than the use of the other coal which, judged by price per ton alone, appears to be 25 per cent cheaper.

If we further assume that we install a mechanical device for the better utilization of coal No. 1 (anthracite screenings) which will cut down the amount of unburned combustible in the ash to 38 per cent instead of our preceding 52.6 per cent; the efficiency of our second step (efficiency of combustion) will thus be raised to about 86 per cent (instead of the former 75.6), and because of the better draft control, the efficiency of the third stage (heat utilization) will also rise and reach 70 per cent instead of 64.1. The total or resultant efficiency will then become 50.15 instead of 40.3 as before, and the anthracite screenings will prove about 17 per cent more economical than bituminous. Our task is next to determine whether the gross saving after providing for interest on investment, depreciation, maintenance, and labor will leave a net saving sufficient to warrant the installation necessary to burn that grade of fuel.

To determine these efficiencies, certain points which have not yet been discussed should be carefully noted. It is self-evident that in determining the cost of 1,000,000 B. t. u., the cost of additional freight, handling, removal of ashes, etc., must be taken into account and must be determined on the basis of the average percentage of ashes in the coal we are considering. In some cases, however, out of several lots of coal received under the same contract, certain deliveries may show a percentage of ash higher than the average and yet prove higher also in B. t. u. This fact is shown by the following analyses, made by the New York City Laboratory and checked by the Bureau of Mines:

Anthracite Pea	Case A	Case B
Moisture	2.6	3.8
Ash	28.7	18.3
Volatile matter	4.2	5.2
Fixed carbon	64.5	72.7
B. t. u. commercial	10,792	10,748
B. t. u. pound dry	11,080	11,173

It is the province of the analytical chemist to determine whether the loss of thermal value in case B is due to endothermic reactions caused by certain constitutents in the ash, or to some other cause. The example, however, is not an exceptional one and it serves to illustrate the small value of proximate analyses without a calorimetric test. On the other hand, the percentage of ash shown by analysis can not at all be taken as a safe guide in estimating the cost of handling, since the percentage of refuse is greater

than the percentage of ash as disclosed by analysis. In our comparison of two coals costing $1.65 and $2.53 per ton respectively, the cost of handling refuse at 26 cents per ton occasions a surcharge

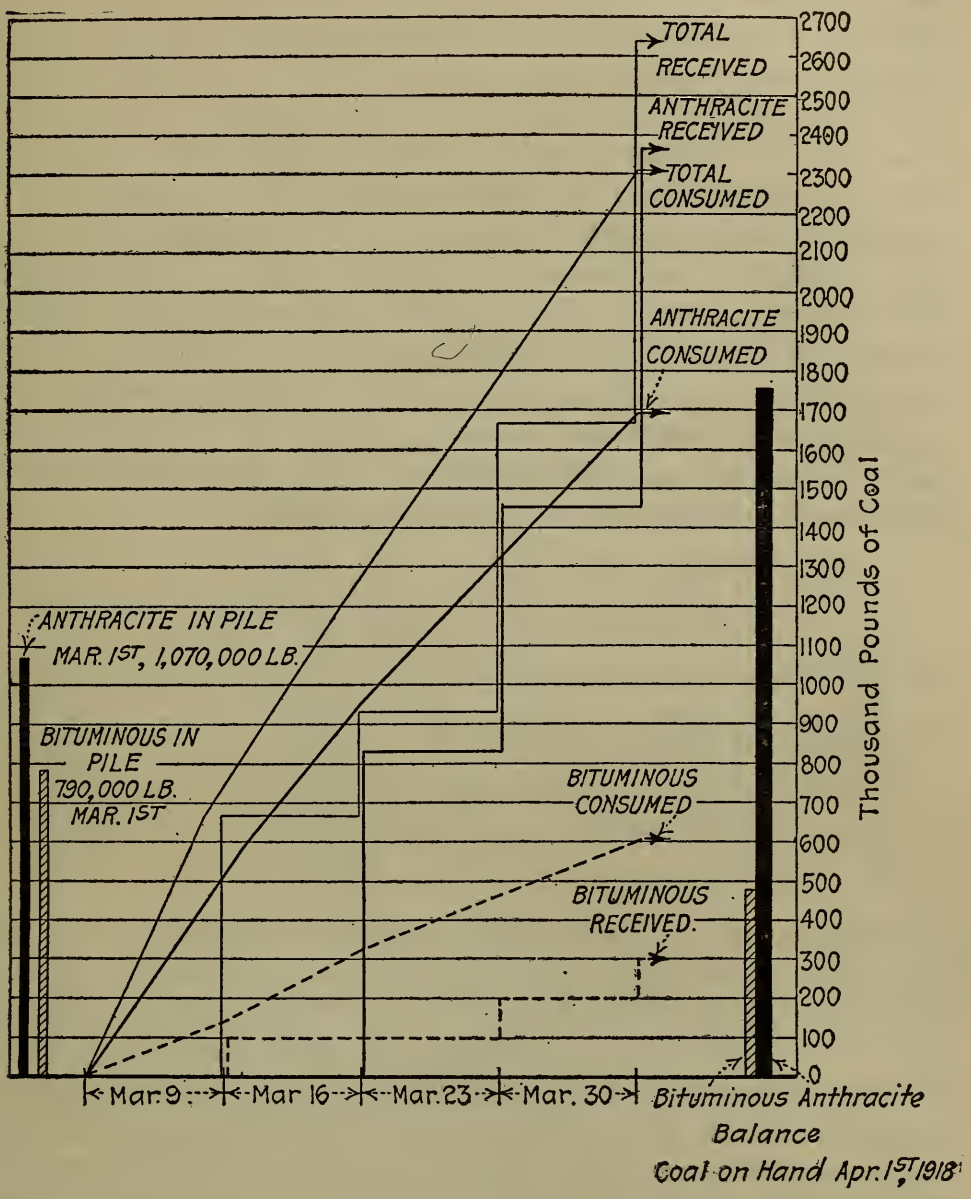


FIG. 35.—WEEKLY COAL REPORT

Graphic presentation of weekly deliveries and consumption of two grades of coal used at a mill power plant. Balances to hand at the beginning and at the end of the month, shown by vertical bars, indicating depletion of bituminous coal pile and accumulation of anthracite.

of 9.88 cents and 2.6 cents respectively, although the percentage of ashes appears by analysis to be 7 and 18. The practice followed by some companies of basing their figuring on the per-

centage of ash shown by analysis instead of on the average of furnace refuse actually produced, is therefore misleading. The second point which should always be kept in mind is the wide range of actual heating power apparently exhibited by the volatile matter, if we consider the heating value of fixed carbon as a constant and consider the ashes to be inert. A high percentage of volatile matter therefore does not necessarily mean an increase in the resultant heating value of a coal. The number of B. t. u. in one pound of volatile matter in coal, as shown by actual burning of the coal in a bomb calorimeter, appears to vary from 40,000 B. t. u. down to a negative value. It is apparent that the heating value of the volatile combustible, very high in the case of high percentages of H and CH_4 for instance, can not descend below zero even if the volatile matter were composed of absolutely incombustible gases as CO_2 N, O and the like. Nevertheless, two samples of different coals repeatedly analyzed by different chemists give the following results:

Kind of Coal	No. 1	No. 2
Size	Run of mine	Pea
Moisture	1.5	3.9
Ash	7.2	15.0
Volatile matter	15.7	4.6
Fixed carbon	75.6	76.5
B. t. u. commercial	14,293	10,792
B. t. u. dry	14,510	11,230

In sample No. 1 the heating value of one pound of the fixed and volatile combustible free from ash and moisture would be 14,293+(0.756+0.157)=15,655 B. t. u. The percentage composition of the combustible considered by itself is 17.2 per cent of volatile matter and 82.8 fixed carbon. As the heating value of carbon is 14,544 B. t. u. per pound, the 82.8 per cent of fixed carbon would account for 12039.73 B. t. u. Therefore, the 17.2 per cent of volatile appears to be credited with 15,655—12,039.73 B. t. u.=3615.27 B. t. u. This is equivalent to a thermal value of 21,019 B. t. u. per pound.

In sample No. 2 the heating value of one pound of combustible free from ash and moisture would be 10,792+(0.765+0.46) =13,307 B. t. u. The percentage composition of a pound of combustible in this coal taken by itself would be 5.67 per cent of volatile matter and 94.33 per cent of fixed carbon. Taking again

the constant heating value of carbon at 14.544 B. t. u. per pound, the fixed carbon in this second sample alone would give 13,179 B. t. u. which is 412 B. t. u. greater than the heating value of a pound of the combustible with the volatile matter included. In other words, our 5.56 of volatile matter appears to have a minus thermal value of 412 B. t. u. or a negative quantity of heat which has somehow disappeared in the combustion of the coal, either due to error in analysis or due to endothermic reaction.

It is necessary to determine carefully to what degree of efficiency the respective kind and size of coal can be burned on the grates and under the condition with which the plant must operate. High percentages of combustible in the ashes are often due to unsuitability in the design of the grate, the force of draft used, the size of coal fired, etc., and each individual case should therefore be examined separately. To determine in any particular instance whether it would be more economical to change the coal or to alter the furnace is a rather complicated problem, because the local factor, which is of great importance, must be carefully and minutely examined and its influence computed.

Similar practice though in a somewhat different procedure should be followed in selection and purchases of other supplies, parts and articles needed. The value of lubricants, gaskets and any other article cannot be determined either as quickly or as easily as this of fuel for the reason that the period of its usable life is sometimes very long and it has an indirect effect on numerous other plant functions, such as the possibility of maintaining the best operating conditions as to vaccum, freedom of leaks, etc., on frequency of replacements involving extra labor and idleness of equipment; on costliness of repairs and maintenance; on safety of employees; on freedom from accidents, interruptions, etc. In order to intelligently determine the service advantages, it is futile to limit the considerations to the mere cost and life of an article or supply since it is necessary to account for all these indirect factors; though again the general criterion should be not the price per piece, pound or gallon, etc.; but per unit of time and output or time alone if load has no determining effect. The method of determining relative values of materials in this group in general at least should, therefore, be based on (1) record of performance (see Figure 44), (2) on the close analysis of operating and maintenance cost, and (3) on records of interruptions and idleness (See Figures 28, 29 and 95).

Managerial Functions

Those directing the production of power, or of any other commodity, cannot ignore the responsibilities coupled with their authority. Waste in any form means the ruination of the individual enterprise, as well as the undermining of the prosperity of a community upon which the business depends and which it should serve. It is quite obvious that most of the losses occurring in operation are due to imperfect organization, lack of knowledge, with resulting poor methods, but it is equally evident that no improvement along these lines can be made until we learn how to master the materials we use. This function is decidedly managerial, inasmuch as workmen, firemen, engineers, etc., are expected to use the equipment, supplies and materials provided for them, and if they are unsuited to the purpose of attainment of predetermined results the entire blame rests upon those responsible for such handicaps. The functions may be divided into two main groups, Care of Materials and Care of Equipment, both being closely and intimately correlated and depending one on the other.

The organization to care for materials embraces the following details:

a Selecting
b Purchasing
c Testing
d Storing.

Similarly the care of equipment embraces:

a Scheduling maintenance
b Specifying work
c Providing labor and material
d Instructions
e Compensation

Care of Material

All materials used in connection with power production are controlled by the plant office, storekeeper being the custodian of materials from the time of receipt of the article purchased until these articles are issued for use. To facilitate identification of stores for charges, etc., all stores are classified into five groups:

Raw material as the name indicates, is the material which is converted into product thus losing its identity; for instance, fuel.

Supplies are standardized materials used in the plant, being neither converted into product nor forming part of the equipment, such as lubricants, stationery, cleaning materials, tools and implements, etc.

Maintenance stores include all such articles as are used for maintaining the plant and equipment in perfect operating condition; these include spare parts, gaskets, transformer oil, boiler compound, motor brushes, etc.

Second-hand stores. All returned parts of the equipment not needed temporarily are returned to the store, repaired and issued subsequently in preference to similar, new articles.

Scrap and refuse. All material that has lost its usefulness for the plant is turned over to the store to be sold or otherwise disposed of, as for instance, old boiler tubes, brass parts, old grates, ashes, burned out electric lamps, etc.

When the plant office establishes as standard a specification for material, the purchasing agent is notified and no other article should be substituted unless such course is unavoidable and the plant office is notified in advance so that necessary measures can be taken to minimize the ill effect of the use of that which is less suitable. Such material as needs constant testing is sampled and submitted to the laboratory for test and report prior to the use of the new delivery. Besides coal, such a procedure may be found necessary for fire brick, transformer oil, new unclassified purchases, etc.

The storekeeper is the custodian of all material in the plant. As every article represents money paid for it, the same care must be exercised over it as for cash in a safe or a bank. Receipt, storing and issuing are carefully recorded and the following seven rules rigidly observed:

1 Check every delivery as to quantity and standard of quality

2 Have only the prescribed quantity of each article on hand

3 Order new purchase only when amount left in store is equal to that designated as "order point" *i. e.*, just enough to last until a new supply reaches the stores

4 Issue from old stock until exhausted. Never mix new and old lots

5 Issue only on presentation of store issue slip properly indorsed

6 Orders, issues and permanent balances of stores shall be handled through the plant office

7 Take care to protect stores against deterioration.

Small quantities of constantly needed stores may be kept in a sub-store and handled by the watch engineer as the storekeeper's representative in his absence. He should be responsible for the lot issued to him on a special store issue card.

As the most important item of material used in a power plant is coal, special problems are presented in its care. The quantity of coal to be stored is a complicated question depending on numerous local conditions which cannot be discussed here at length. Plant operation free from interruption is a chief factor; deterioration and possibility of spontaneous combustion should also be taken into account. Interest on the coal pile seldom receives due attention. All deliveries being unequal in quality and character, it is undesirable to mix various coals, and should carefully be avoided. The chart shown in Figure 35 is very serviceable as a means of reference and control, since it shows at a glance the quantity on hand on any day or week, quantity of each delivery, daily consumption and quantities of each grade or kind of coal on hand and other useful information. (For further information see Chapter IX.)

Necessity of Planning for Handling of Material

The next function of management is care, handling and moving materials. It is obvious that to execute any work requiring use of material we must know:

1 What material is needed
2 Where it is needed
3 When it is needed
4 What is to be done with it.

Very often when certain work is to be done in a plant, merely a general order is given as to what is wanted. The man is left to find out for himself at what time the machine will be available to do the repair. When he starts work, he discovers that he needs certain materials; next he hunts for these and when he gets them, takes plenty in order to avoid shortage while working; then when he is through, the left overs are stuck away somewhere in a cupboard. The good excuse is "to have

it handy next time," but as it regularly happens that "next time" he can't find it even if he remembers where he put them, the story merely repeats itself; waste of time to find out what is needed, waste of more time to go and fetch it, waste of excess material. Yet no mechanic could be blamed for it as his job is to do the work, not to manage the power plant.

We detail duties of such nature to the engineering or production office. The experience of the plant engineer aided by standards and records helps him to avoid mistakes and save the time of the mechanic and on the cost of the job. While the function of maintenance engineer will be explained in Chapter V, we should remember in this connection that the care of issuing, moving and using materials is one of the principal functions of management and it should be well organized before a full success may be expected from the work of maintenance crew.

Chapter V

MASTERING MAINTENANCE

IN the preceding chapters we have shown the relations in which the economy of production stands to equipment installed and materials used. The consideration however was from the viewpoint of potentiality embodied in a given equipment or material; the mode of its use was not discussed. It is obvious that perfect equipment as the most suitable material may be misused, abused or put to wrong purpose with an inevitable result that its inherent, potential advantages are not fully realized. Under such mistreatment of physical elements of a plant the difference between good and poor mechanism or supply may entirely vanish if the former is poorly used and the latter is taken the best advantage of; indeed, it may often be shown in practice that in the latter cases, the efficiency and economy are higher, both relatively and absolutely. One of the frequent causes is purely psychological in its nature—management and other employees, realizing the handicaps they are put on, exercise better judgment and care in securing creditable results from poor plant than the organization which is complacently proud with admittedly up-to-date means of production at their disposal. Such is not an infrequent case in large central stations, largely depending on the engineering specifications and investments in up-to-date equipment for securing results that seem certain, and losing sight of importance of methods of operation and maintenance.

We must therefore pass to a considerations of that function of plant management which aims to maintain the equipment and plant in a condition fit for the most economical and efficient production. Proper upkeep of power equipment is of far greater influence on output and economy than it is in many other manufacturing enterprises. Neglect to clean the heating surface of boilers, to prevent numerous little leaks, etc., seriously affects the fuel economy. Careless, sporadic inspection of equipment is much more hazardous in power plants than anywhere else, as it may result not only in crippling one section of a plant, or cause poor service, or even temporary shutdown, but is liable to cause more serious disaster. The old

saying that "a stitch in time saves nine" is nowhere more true than in the power plant.

To secure the possbility of obtaining uniformly good results from proper methods of operation—that is, make it possible for the men to live up to their tasks and, if the bonus award is offered, to earn it, the plant equipment must be maintained at all times in a uniformly good operating condition.

Distinction Between Upkeep and Repair

The well-known fact that the efficiency of equipment depreciates in time is primarily due to poorly planned or unsatisfactorily carried out maintenance work. As a rule it is not so much the result of natural wear and tear of machinery as it is the consequence of accumulation of residue of processes that diminish the efficiency of the elements of equipment thus affected. The wear and tear in a large degree is the consequence of this first cause and generally speaking is not nearly as difficult to handle, for it is a great deal more apparent even to a casual or superficial inspection.

The ill effects of deposits from feedwater in the form of scale or grease on the surface of heaters and boilers, or from fuel on heating surface of boilers and economisers as soot and cinders cannot be correctly appreciated and measured unless a record of instrument readings is closely studied and scrutinized. In the plants having no such instruments the effect of dirty heating surfaces can not be measured or at least correctly allocated as the drop of efficiency may be ascribed to other causes, one guess being as good as another. The inevitable result is that cleaning, soot blowing, washouts, etc., are made at intervals set at random, chiefly determined by the looks at the time of the last cleaning. If, as it often happens, the nature of fuel was changed or more or less load was carried during the period, or draft was adjusted differently or the content and nature of scale-forming matters in the water has in interim undergone a change,—the best prognostications as to reasonable length of time between cleanings are of very questionable value. Similarly, the deterioration of oil in circulating system, in transformers, etc., is not readily noticeable unless suitable tests are made periodically. To the contrary any break-down, loose working, leak or other damage to the parts of equipment proper is immediately apparent and therefore has more chance to be promptly attended to.

The cardinal difference between the aims of upkeep and repair is that upkeep of the plant, as the name implies, tends to keep up

the efficiency of equipment and plant in its original state, while the repair mends or replaces the disabled, worn-out or broken parts. *The repair* is thus concerned with maintaining the *original form* of plant and equipment, while the *upkeep* aims at preservation of its *original efficiency*. Both functions are inseparable in such instances where the wear and tear of equipment impairs the efficiency of operation, as may be in case grates burnt out or babbitt melted from overheated bearing, yet it may be entirely independent, as for example in case of repacking a gland or blowing off the soot or changing oil or cleaning out the filter—these being purely and simply upkeep jobs; any repair job (unless it is done on an utterly useless part) contributes to the proper operation and maintains general efficiency of the plant though it might be a trifle like a broken window pane, or a chipped spot on the floor.

Both repair and upkeep thus constitute two phases of one important function of mastering production, namely *maintenance* and any sub-classificatoin of jobs as are frequently met in practice are merely formal, bookkeeper's classifications to denote either that the work was attended by operating force or by repair crew and sometimes to distinguish to what expense account the charges are to be made; practical value of such differentiations is limited to specific cases only, the expenses of both groups contributing to the possibility of operating the plant with minimum waste.

One technical detail may however be pointed out in passing, regarding the broad principle of classification of expenses on supplies and materials used in maintenance. Articles, such as boiler compound, lubricating materials, etc., that are used continually in order to maintain the efficiency of operating processes at the best point, are obviously consumed in proportion to production and may be charged directly to operating expense account as materials directly used in the process of converting the forms of energy handled. On the other hand such articles as used in maintaining the plant in its best operating conditions but form an integral part of equipment or plant after they are put to use, for instance paints, oil in switches and transformers, gaskets and the like should be charged to the maintenance account. Such a distinction, as we shall see later, is of material help in an intelligent analysis of cost reports and should therefore not be neglected.

Depreciation of Efficiency

While wear and tear on machinery (obsolescence belongs to an entirely different plane) depreciate their value, the efficiency of the

machinery is likewise gradually depreciated. Similarity of the process may be grasped if we will consider as an example the service life of a simple unit, say a pump. A new pump in perfect condition is capable of delivering a certain number of gallons against a given pressure (foot-pounds) for a definite input of a certain volume of steam at given temperature and pressure (foot-pounds per B. t. u.). As the valves and plungers on one side, piston rings and valves and link motion on the other wear out, the pump is losing its value in some relation to the work done and, as this may be assumed a func-

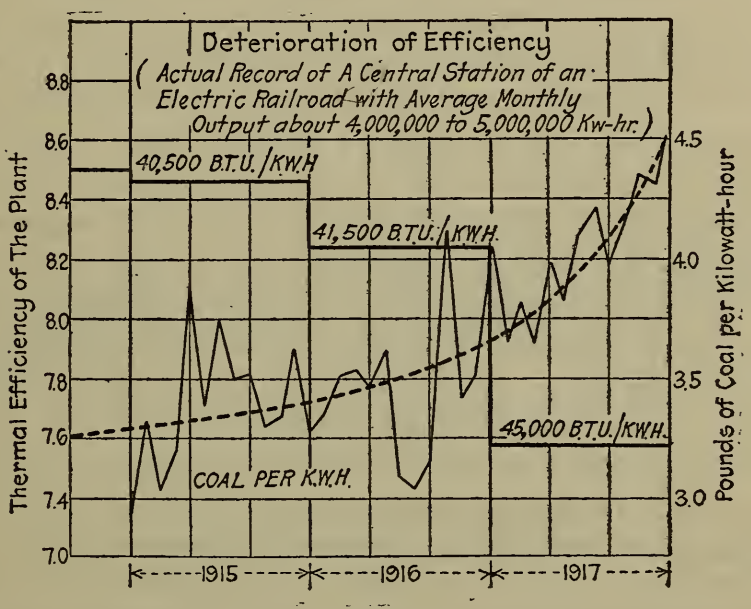


FIG. 36.—DEPRECIATION OF PLANT EFFICIENCY DUE TO POOR MAINTENANCE

For over three years the policy of this central station was to "economize" on maintenance. This caused increase of B.t.u. consumption per Kw.h. by about 5,000 B.t.u. or extra expenditure of 10,000 tons per year. Finally this company has entered into an arrangement for purchase of power from outside. The entire plant was thus rendered useless and fare increased.

tion of time, the pump will be worn out and unfit for use at the end of a certain period. At that time its value will be depreciated to that of the material from which the pump was made (scrap value), the difference between the first cost and the salvage price being transferred into the value of water pumped during this period. At the same time the efficiency of the pump is similarly decreased, as slippage, leaks, etc., increase steam consumption until finally no amount of B. t. u. input will cause any quantity of water to be pumped against even slightest pressure or elevation. At this point the pump, as a pump, ceases to exist and becomes merely a burdensome occupant of space.

In practice, however, the unit is not allowed to wear itself out in this manner but from time to time is put under repair, leakages stopped, etc. This maintenance work obviously produces three distinct results: extends the life of the unit, invigorates its dropping efficiency, and involves additional expense. Were it possible to infinitely maintain our unit in its prime of working condition, the depreciation charge would practically cease to exist and we will have only interest on original investment and cost of maintenance (rent of space, etc., being disregarded for simplicity). Now, as a matter of fact, a material of which the pump is made wears out and the expenses of maintenance and replacement of weakened and worn-out parts finally exceed the amount of money outlay necessary for a new unit, that is, the cumulative annual maintenance expense plus the unrecoverable loss of efficiency becomes larger than the annual depreciation of a new unit plus or minus the difference in the interest charge. Within the entire period of the life of our equipment there are thus periods between repairs when the efficiency is gradually deteriorated (*i. e.,* number of B. t. u. per foot-pound of work increases) and then measures are taken to restore, as nearly as possible, the original efficiency. If we were to carry the repairs so thoroughly that after every repair we would be able to secure the same degree of efficiency as that for which the unit was designed then, we would merely be confronted with accumulation of losses between the repairs, but as it would mean complete rebuilding of the unit in the course of time (which as we have seen, may become prohibitive in price, or undesirable from the viewpoint of advance in the art), the usual course is to restore the inherent efficiency only in a measure. The losses due to the deterioration of efficiency do therefore accumulate more rapidly as the age of the unit advances.

Whenever a sinking fund is provided for amortization, the object of which is to take care of the eventual replacement of old equipment and, as the use and attending it wear and tear are necessary for production, such expenses and outlays are legitimate and necessary parts of the cost of product. The condition is somewhat different however in case of depreciation of efficiency. If the efficiency of worn-out or clogged equipment drops, as it invariably does, the fuel consumption per unit of output increases; sometimes the productive capacity of equipment is also diminished, but in both cases the production expenses increase through larger fuel bill and reduced productivity per dollar invested and rent. The effect of such rise of production expenses is either reduction of profit, if price of product can not be advanced, or inflation of price of product. But

whether the owner or the public has to stand the consequence, the fact is that the operation is getting more inefficient and waste and cost are increased without any value being added to the product. To establish a fund parallel to the sinking fund to take care of or amortize this increased cost of inefficient operation thus making the ultimate consumer of the product contribute to that "inefficient fund" would appear unjust and impractical, yet this is exactly what is being done to-day under another name. *Any charge or price fixing that is based on the cost of operating the equipment in the*

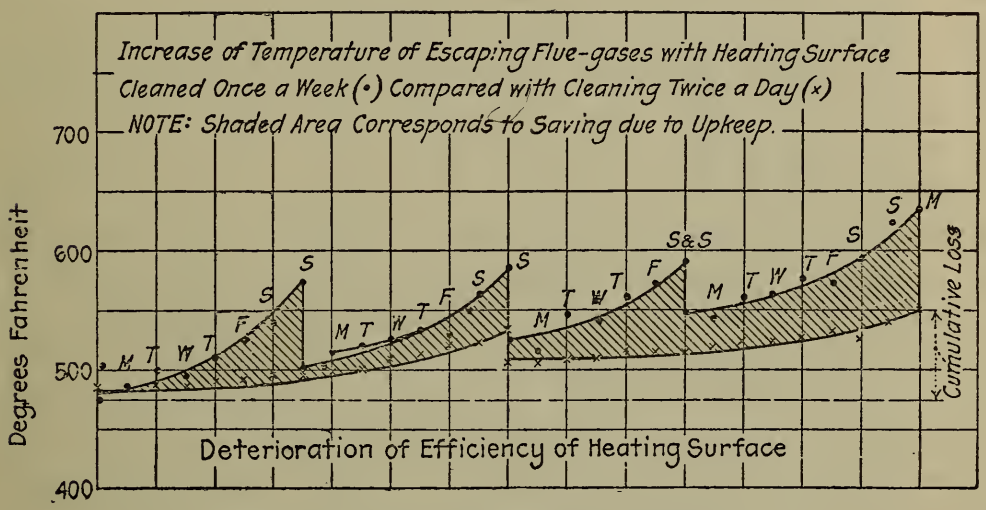

Increase of Temperature of Escaping Flue-gases with Heating Surface
Cleaned Once a Week (•) Compared with Cleaning Twice a Day (×)
NOTE: Shaded Area Corresponds to Saving due to Upkeep.
700
600
500
400
Degrees Fahrenheit
Deterioration of Efficiency of Heating Surface
Cumulative Loss

FIG. 37.—DETERIORATION OF EFFIENCY

The conductivity of heating surface decreases rapidly with an accumulation of soot and scale. The losses accumulate rapidly during the week when the cleaning is made every seven days, whereas when cleaning is made daily, at the end of two weeks period, the losses are considerably reduced. Similar effect is observed when the boilers are turbined and washed out instead of preventing formation of scale.

average condition of repair and not at its best operating economy is a form of taxatoin to cover the loss caused by imperfect maintenance.

To illustrate this fact graphically, Figure 36 has been prepared. For several years the efficiency of a large central station was gradually dropping, due to unwise economy in maintenance expense, until finally it was consuming 35,000 more tons of coal than it should. Obviously, the operating losses caused by depreciated efficiency may be materially lessened by shortening the periods between cleaning and overhauling of various units of equipment. Figure 37 represents graphically the general truth of this statement, the limiting factor being the cost of maintenance work as opposed to corresponding increase of operating expenses for the longer or shorter periods. Another, and a more general consideration of course, is the safety of operation with infrequent overhaulings. In any event, as has

been stated before and as shown in Figure 37 an allowance should be made for the unrecoverable loss of efficiency (dash curve) for at least a fairly long interval, such as, gradual increase of water rate in turbines as the blading is slowly getting worn out, or even in less prolonged intervals as for instance in the case of blowing off soot from heating surface. While in this case, the frequency of operating the blowers is determined by the cost of their operation (use of steam, wear, loss of fuel during blowing period) as compared with gains due to better heat convection, the entire accumulation of soot is not totally removed by the action of blowers and thus after each consecutive blowing the former efficiency is not fully re-established and eventual scraping is to be resorted to at the end of a longer period.

Such inevitable loss of efficiency even under the best care and maintenance is not to be confused with altogether preventable losses due to neglected upkeep: being borne out of the physical nature of the processes or machinery they are unavoidable operating expenses, at least after a thorough study and experimentation establishes beyond question that the manner in which the maintenance is taken care of is all that it should be. An example of depreciation of efficeincy due to this cause of slow wear and tear may be seen in Figure 25 representing the efficiency of a 2500 kilowatt turbine at the time of its installation and a few years after, both tests being figured on the basis of the same steam pressure and superheat.

Inasmuch as the average loss of efficiency throughout this period is equivalent to an increase of steam consumption of 1 pound per kilowatt, we may readily figure out the depreciation of its use value. During this period the turbine has generated 40,000,000 kilowatt hours and therefore on the basis of the above average, it used the same number of pounds of steam costing 25 cents (coal value only), the total loss is equal to $10,000. If during the last year in question this turbine caused say $4000 annual loss it means the same as if any other form of capital failed to earn the same amount of income. An average financier will readily appreciate the meaning of non-revenue producing investment; now, carrying this simile further in a deteriorated equipment we have an investment of capital, yet for the privilege of investing it an annual charge is made against the capitalist, and the amount of this charge is increasing with every year. Another side of the situation is the social significance of the losses caused by deterioration of efficiency of equipment the maintenance of which was neglected (the nature of this loss was exposed in the chapter on mastering materials) and as in the case of misused

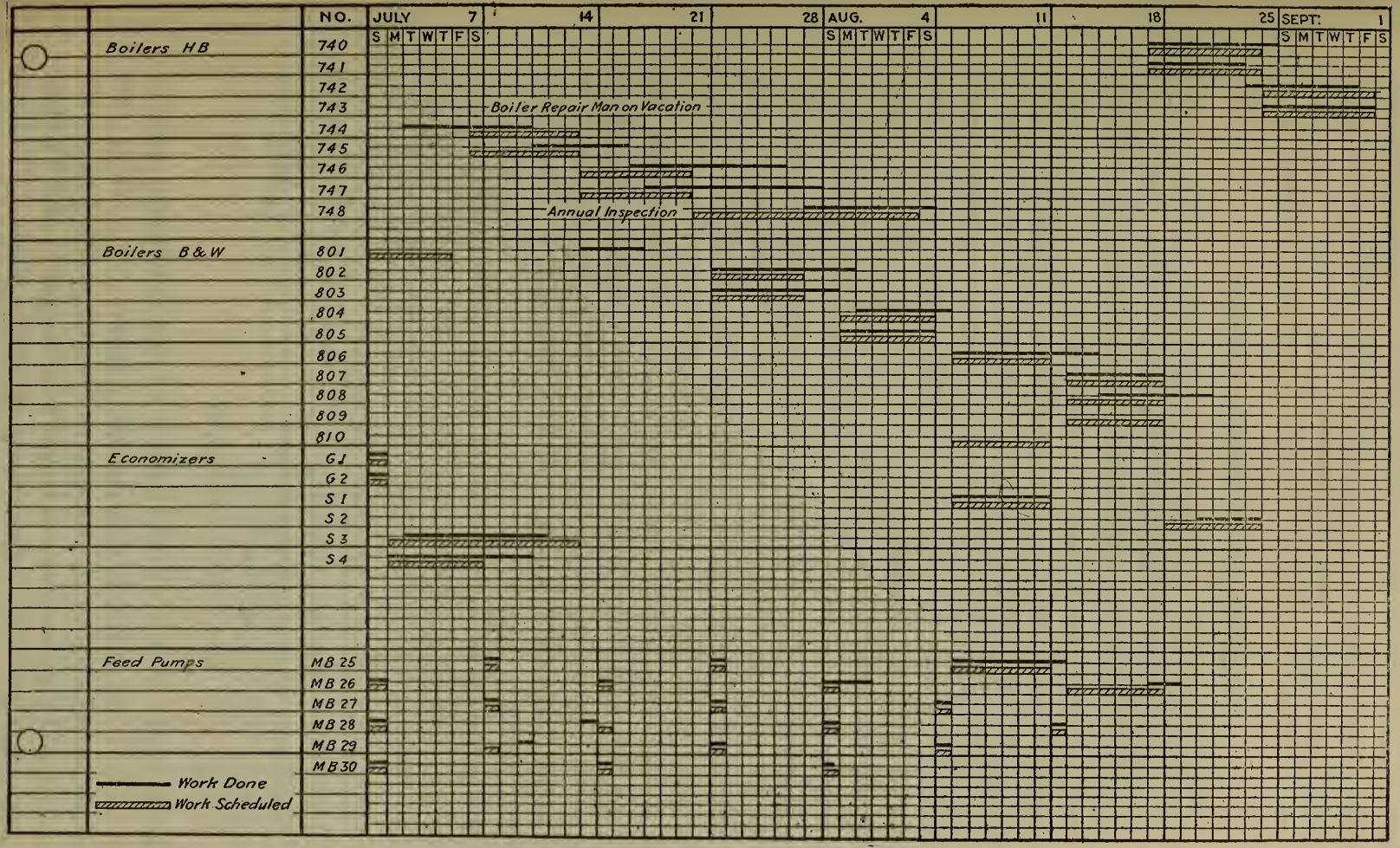


FIG. 38.—SCHEDULE OF MAINTENANCE WORK

Opposite each piece of machinery a red line is drawn (shaded) extending over the period allotted for maintenance work. Black lines are drawn for the period the work was actually being done. Chart visualizes jobs ahead, those progressing, lagging and completed. Thus job on boiler No. 810 is four weeks late in starting; on economizer S-1 done in schedule time, job on boiler No. 744 was done ahead of time due to shortage of labor.

materials it represents not only an irretrievable dissipation of labor, but is at the same time one of the processes of accumulation of capital as the community is paying the expenses of all losses of production plus an accepted interest thereon.

Planning Maintenance Work

The maintenance work appears, in the light of the above considerations, as something more than mere mechanics' work. The maintenance of plant in the best possible operating condition assumes the importance of a fundamental function of management. Its influence is extended in three directions: (1) conservation of natural resources and labor power, (2) satisfaction of fundamental prerequisites of economic prosperity of the country which is able to produce more and cheaper goods with correspondingly higher wages, and (3) improvement of working conditions for the men engaged in a well-kept, properly maintained establishment.

The management thus faces the responsibility, not only of safely keeping the physical properly, but also it must see to it that the plant does not become a source of loss of materials and labor; that it does not cause higher cost of production than it might be in a well kept plant; that the productive equipment is not rendered idle because of neglected or ill timed repair; and above all that the physical conditions are not permitted to cause unnecessary fatigue, degradation or depression on the employees not to say that it never should become a source of a danger to their life, limb or any mental or physical faculty.

Mastering the maintenance so as to satisfy these elementary requirements of economy, production, decency, and safety should be planned so that the following requisites are always satisfied:

a Highest all-around efficiency obtainable
b Maximum capacity available
c Minimum idle expense involved
d Steady employment provided
e Danger and discomfort eliminated.

From a study of the characteristics of the equipment used in the plant and from the log of daily performance, two things may be definitely established: the maximum efficiency under best condition for which any given piece of apparatus is capable and its daily actual performance. Close scrutinizing of these two may disclose that in every day practice the efficiency obtained is lower than that

possible. This may be due to one of the three main causes: (1) faulty method of use or operation, (2) unavoidable handicaps and (3) run-down physical conditions. In this latter case, cleaning, overhauling, or repair should be undertaken. In practice, however, it is sometimes extremely difficult to draw a distinct responsibility

ELECTRICAL INSPECTION ROUTE CARD

MAKE THE FOLLOWING INSPECTIONS IN THE ORDER NAMED

JAN. 1 TO JULY 1, 1916.

WATCH 7 - 3 — EVEN SUNDAYS

APPARATUS	2	16	30	13	27	12	26	9	23	7	21	4	18	
1 - 25 Cy. Gens.	✓	✓												
2 - No. 11	✓	✓												
3 - No. 13	✓	✓												
4 - No. 12	✓	✓												
5 - A	✓	✓												
6 - B	✓	✓												
7 - C	✓	✓												
8 - D	✓	✓												
9 - S	✓	✓												
10 - CS	✓	R												
11 - T	✓	✓												
12 - Coal Larry No. 3	✓	✓												
13 - " " "	✓	✓												
14 - Battery Blower	✓	✓												
15 - Economizer	✓	✓												
16 - Coal Elevator (Ry.)	✓	✓												
17 - Coal Crusher	✓	✓												
18 - Coal Conveyor	✓	✓												
20 - Ventilators	✓	O												
21 - Ash Locomotive	✓	✓												
22 - Oil Filters	✓	✓												
23 - Oil Pump	✓	✓												
24 - Control Bench	✓	✓												
25 - Feeder Board	✓	✓												
26 - Local Ser. Board	✓	✓												
27 - Exciter Board	✓	✓												
28 - Signal Board	✓	✓												
R - Repair Suggested														
O - Ordered out														
SIGNED_____	I	P												

FIG. 39.—INSPECTION ROUTE CARD

Stitch in time saves nine. Inspectors make routes and attend to minor adjustment at once themselves, if O.K. they mark on the card ✓; if repair needed R, and if it is dangerous to keep the mechanism in use they order it out—O. These cards are protected from soiling by a celluloid envelope with a slot cut in to write marks.

but comparatively simple to establish definite periods for regular cleaning and overhauling of any and all parts of whole units of equipment. This is done on the basis of observation modified by (1) cost of cleaning or overhauling as compared with the gain resulting and (2) opportunities to withdraw equipment from operation.

Unquestionably the most convenient way to lay out and follow up the plan for this work is the graphic schedule of maintenance work (see Figure 38) and as a means of protection against troubles and possible interruption of production, frequent and regulated inspection should be made in accordance with a well laid out route and notes of findings to be made on the route card (see Figure 39).

Following up this plan it is possible to always maintain a maximum capacity of equipment available for production. Two factors contribute to that end. First, inasmuch as certain machinery loses its productive capacity if run for a length of time without due attention, frequent cleaning and overhauling makes it possible to secure the same result from a smaller number of machines in line. Second, when the maintenance work is being done on schedule, equipment is frequently inspected and its capacity and efficiency may be relied upon, a greater output may safely be secured, not only on the average but during the peaks. This condition considerably relieves the common anxiety as to security of operation in one extreme and as to expense of keeping excessive spare idle equipment in another. It hardly need to be mentioned in this connection, that these results can be secured in an average plant only after thorough overhauling of the entire equipment and gradual putting every unit overhauled on schedule. This takes considerable time, varying not only with the size of the plant and the condition in which equipment was originally found, but depends also upon the nature of the service, spare capacity, available help and facilities, etc.

It inevitably follows that whenever the work is done in accordance with a prearranged plan, whenever a unit is taken out of service for maintenance work, the men and materials ready, and instructions and other facilities available, the work may be prosecuted much more rapidly than in cases when the unit is to undergo overhauling or repair at an unexpected moment, when need of the work to be done were not anticipated, facilities, materials, drawings, etc., not provided and the best fitted men not available. It is to be remembered that the less time spent for maintenance work rendering equipment idle or non-productive, the less is the overhead charge on the product, and as we have shown elsewhere this item in a modern plant

is a very considerable portion of the expense. Furthermore, in cases where ample spare capacity is idle anyway because of lack of load, the speedy completion of maintenance work means not only lower

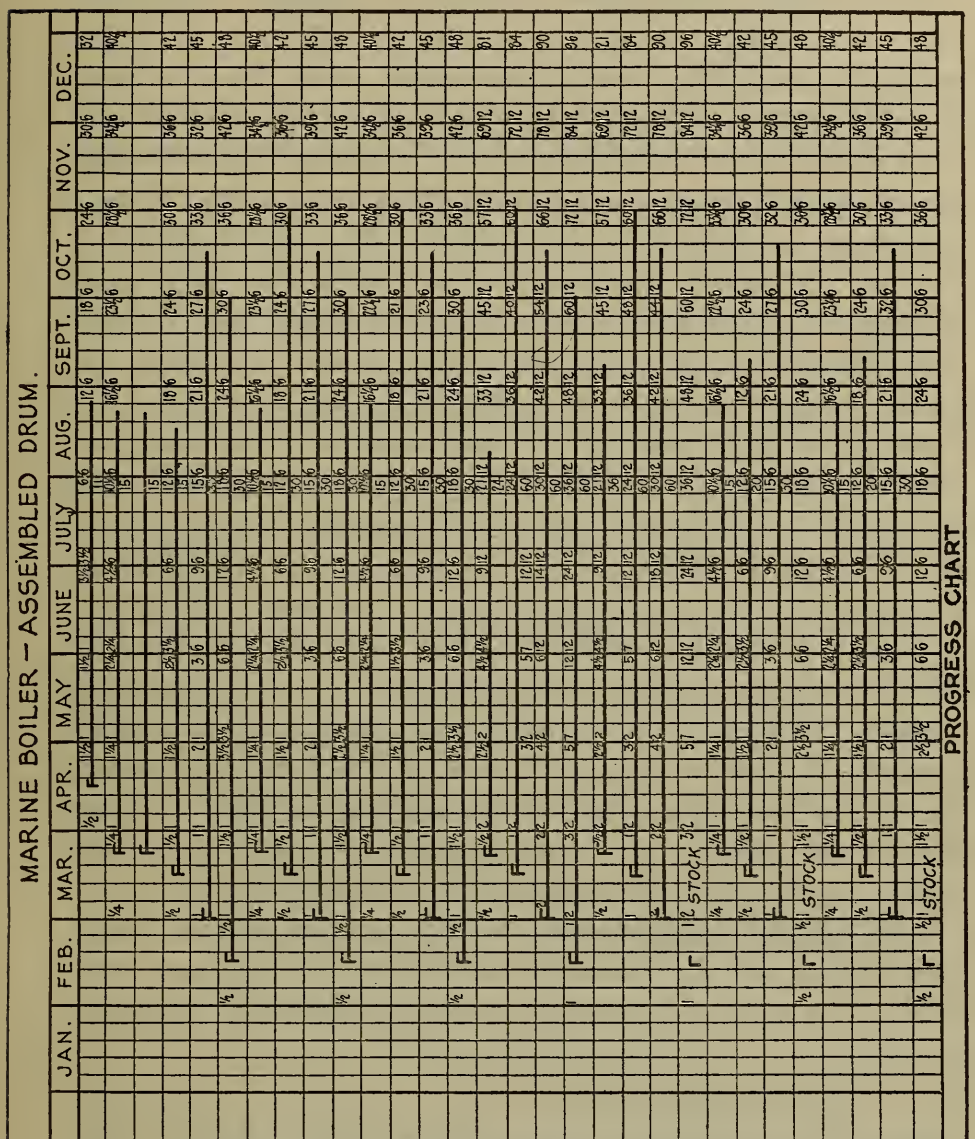


FIG. 40.—PROGRESS CHART—BOILER CONSTRUCTION

This method visualizes progress in construction and has widest possible application. ⌐ Indicates when the job should start; ¬ when it must be completed. Lines drawn indicate percentage of work done to date. Figures in the end of monthly spaces show what should have been done to date; figures at the beginning of the month show task for that month.

expense on labor but a greater safety against unforeseen accident that may render some other unit inoperative, thus sometimes rendering idle and unavailable a portion of the plant equal or even larger than the rest of the plant capacity.

Another outstanding advantage resulting from a well preplanned maintenance work is that scheduling of jobs does away with sporadic rush work followed by periods of laxity of work of this kind. Under such conditions there is difficulty at times in obtaining competent men to make the repairs, temporary help either skilled or unskilled who, frequently unfamiliar with plant details must thus be hired and they usually require a great deal of attention and help from the regular operating force. It is necessary of course to lay off these men when the work is completed and no other is in sight. Scheduled maintenance, as opposed to such state of uncertainty, makes it possible to provide steady employment for a first class competent maintenance man or maintenance crew, as the case may be. Maintenance work being carefully scheduled and planned is carried out continuously; therefore a double advantage is secured: first a smaller force is needed as accumulation of rush work is eliminated, and second, this man or men can count on steady employment and consequently better men will be available for the position. Furthermore, familiarity with plant layout, conditions and service requirements on the part of maintenance men are essential, but what is still more important is the fact that a permanent crew does the work not in a superficial or careless manner as is often the case with temporary men. Moreover, the job is not unnecessarily dragged and delayed as is frequently the case when done by a man temporarily employed who may not see any other employment waiting for him. These advantages of the planned work and permanent maintenance crew are of great importance to both employers and employees and, incidentally breed another valuable by-effect: maintenance men, being thoroughly familiar with the plant, do not interfere in any way with the operating crew either by constantly asking questions or requiring directions and help.

Finally, under such regime, a great deal of danger and discomfort is eliminated. The majority of power plant accidents both to men and equipment occur during repair work and are ordinarily traceable either to insufficient familiarity with peculiarities of plant or to rush and overtime work while sometimes it is due to the fact that the operators busy themselves with maintenance work and overlook their own direct functions. Any one familiar with the inner life of a plant knows with what relief the end of any repair work is usually greeted; yet there is no cause for anxiety or discomfort in a plant where all maintenance work is carried out by a well-trained permanent force, intelligently coöperating with operating men both during the work and in the aim of the work—to maintain the

equipment in the best possible operating condition and not merely perfunctorily comply with order for repair.

Mechanism for Maintenance Work

An automobilist who buys a new car every season and gets rid of the last year model keeps his repair bill low at the expense of enormous depreciation within a short time. Whatever it cost him

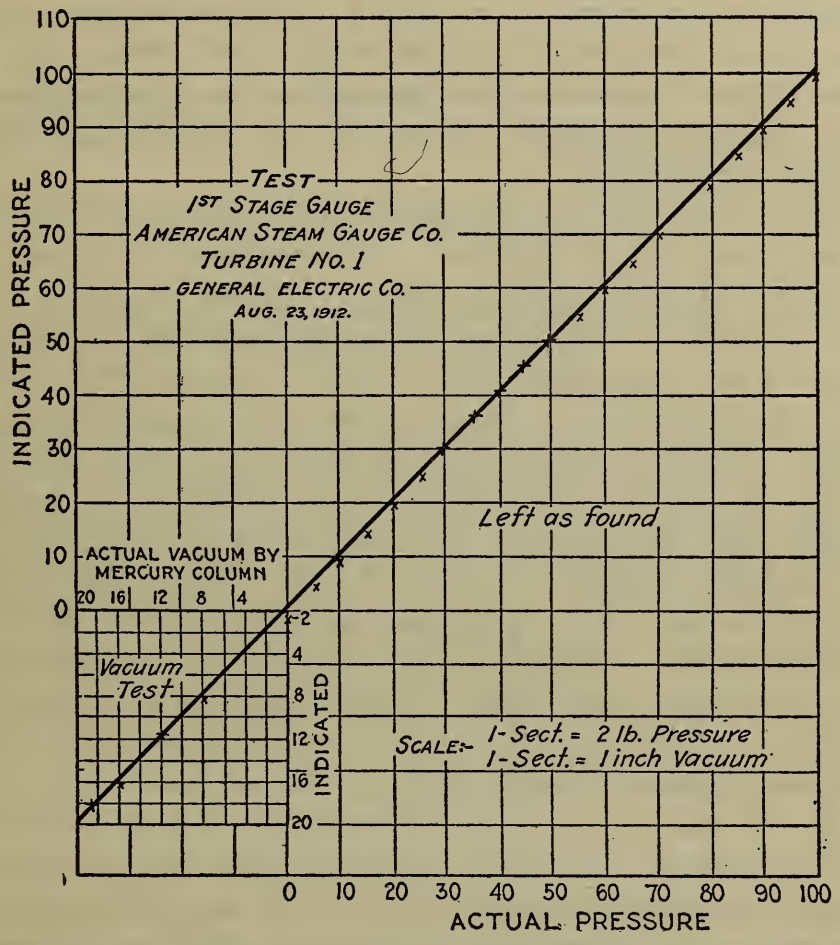


Fig. 41.—Graphic Record of Testing the Instruments

This method of recording the check tests of accuracy is very convenient for electric meters or any other power plant instruments, the correct readings and readings as observed platted on coordinates to the same scale. If instrument is correct the record will fall on diagonal line. If there is minus error readings will be below the diagonal and if there is plus error the readings will be above the diagonal.

he has at least a satisfaction of using new, efficient mechanism. When this gentleman owns a power plant, however, he cannot afford to sell the entire equipment to a second-hand dealer every year and replace it with new machinery and so he keeps what he has as long

as he can, but his dislike for repairs and underestimation of the value of regulated maintenance is ordinarily so great that the cheapest men are relied upon to take care of this inevitable evil—maintenance. The results, in the predominating majority of the plants, are very deplorable and the consumers of its product and thus the country at large pays for the consequences.

Yet, even the best mechanics can do little for maintaining the plant's equipment in a constantly efficient operating state unless they are given the opportunity to do good work. Skill alone, without proper planning and administrative mechanism is always at a great disadvantage. Therefore, the organization of maintenance work and the working mechanism that permits and insures proper care of equipment are essential.

The first problem that comes under consideration is the *time* when any maintenance job is to be done. This presupposes the knowledge of the time when the machine will be avaliable for repair as well as the time when the machine shall be again available for operation. Thus we must know *duration* of available time and from it judge whether time needed for repair contemplated is smaller than this available. Usually the time taken for the work is much longer than it should be, because needed men are not available in the beginning and when they are assigned, they find themselves unprovided with either necessary materials or tools or both. With work scheduled well ahead of time all the needs and handicaps may easily be foreseen and provided. Hence, graphic schedule of maintenance work is the most needed and highly useful mechanism the management must devise. As a rule in the beginning, the work on a schedule discloses many things that are believed to be well known but are not. Nobody is certain as to how much time the job will take, what tools will come in handy, what is the best material to use, etc. Planning therefore by necessity is started on the basis of the best guess and, as experience and observations accumulate, the uncertainties are eliminated and errors of guess corrected. Thus in our maintenance schedule (see Figure 38) we must show not only when the task should start and end but when it actually was started, how long it took to finish the job and when it was actually completed. Red lines opposite each unit of equipment on the schedule show on the time scale the extent of time allowed while the black lines above represent the time of actual performance.

The usefulness of such graphic schedules supplemented with performance records are manifold: (1) analysis of records helps to establish more accurately the time needed for work, (2) gradually

REC'D
FINISHED

OPERATOR

MACHINE SYMBOL

CHARGE SYMBOL

REPAIR ORDER NO.

PARTLY—TOTALLY DISABLED

MONTH	DAY	YEAR	
			____A. M. ____P. M.

PARTS BROKEN OR WORN

CAUSE OF BREAK

WORK IN MACHINE AT TIME

	MO.	DAY	YEAR	A. M.	P. M.
PLEASE MAKE ABOVE REPAIRS BY					
MACHINE AVAILABLE FOR REPAIRS ON					

THIS ORDER MUST BE SENT TO REPAIR OFFICE

FOREMAN

10M Sets—3-19 B136

REPAIR ORDER

OPER. NO.	OPERATION	CLASS OF WORK	WORKMAN	RATE
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

WAGES	EXPENSE	MATERIAL	EXPENSE	TOTAL CHARGES

TO BE KEPT BY REPAIR OFFICE

FIGS. 42 and 43.—WORK ORDER FORM AND ITS REVERSE SIDE

This form prepared in triplicate gives full record of work. Party ordering repair keeps one copy for follow up. Order is sent to repair shop in duplicate; original is kept on despatch board and copy given to workman doing the repair. On reverse side entries are made showing what was done, by whom and how much it cost. When work is completed the summary is entered on repair record card for each unit of equipment.

diminishing time taken shows that the periods between overhaulings, etc., may be lengthened, (3) with conditions of maintenance improving, the schedule may be laid out more definitely, (4) tool-room and store room may regulate the amount of special tools and supplies which they must have on hand to meet regulated conditions and correctly anticipate the demands, (5) inspector or chief engineer may save a great deal of time by following up the preplanned work, (6) appropriations for maintenance work may be made more accurately.

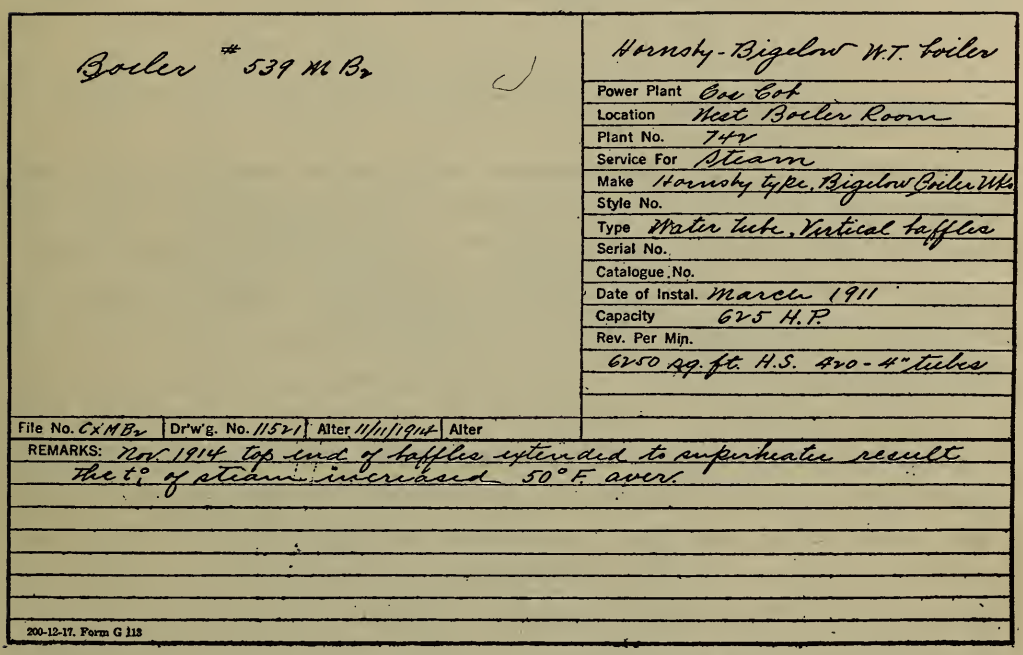
A similar method of charting the performance as it should progress and as it has actually lived up to the schedule is readily applied to any new or construction work with even more gratifying results. While charts like Figure 38 were used by the author for many years they were more recently adopted by various governmental agencies in order to assist and control such activities as building new power plants or construction of boilers, boats, etc. (see Figure 40).

The second element of this mechanism for planning the maintenance work is regular inspections of every portion of the plant equipment in order to detect any possible weakness or unsatisfactory working condition developed between the periods of scheduled overhaulings, cleanings and repairs. Figure 39 illustrates a form that helps in carrying out the inspection in time and in sequence.

The follow-up under such a regime is at once simple and safe; it eliminates guess and minimizes the break-downs or other causes of interruption. The engineer or plant clerk following up the graphic schedule and inspector's reports prepares work orders (see Figures 42 and 43) and sees that men, materials, and tools are on hand at the time the machine can be made available for repair or any other work to be done on it.

While the work is progressing, the data covering same are accumulated on the back of the work order, and upon the completion of a job it is then known how long it took and how much labor and material was spent. From these we know the cost of repair and the record of same is kept for each individual unit (see Figures 44 and 45). The data from these cards if completely and accurately filled out are of immeasurable value in determining what materials produce the best results, last longest and shows the lowest cost in service, what method of repair gives better satisfaction and takes minimum time, etc. Moreover, comparison of maintenance records of machines of different make but in the same service gives a basis for preference for future orders of replacement; similarly careful perusal of these records often discloses that certain parts of other-

wise satisfactory machine give constant trouble, in which case, redesign or even a minor change is capable of producing a very material improvement. In many instances this method led to the discontinuation to purchase cheap supplies and materials proving themselves short lived and thus wasteful; again it has been proven in some cases that much cheaper material gives excellent satisfaction; thus proving that no generalities nor fixed policy of purchasing department should be seriously considered. The cost of maintenance in all cases, under such practice goes down after a year or so of experience is accumulated, which frequently causes no small surprise on the part



Boiler # 539 M Br

Hornsby-Bigelow W.T. Boiler

Power Plant Coe Coal
Location West Boiler Room
Plant No. 747
Service For Steam
Make Hornsby type, Bigelow Boiler Wks
Style No.
Type Water tube, Vertical baffles
Serial No.
Catalogue No.
Date of Instal. March 1911
Capacity 625 H.P.
Rev. Per Min.
6250 Sq. ft. H.S. 420-4" tubes

File No. CxMBr | Dr'w'g. No. 11521 | Alter 11/11/1914 | Alter

REMARKS: Nov 1914 top end of baffles extended to superheater result the t° of steam increased 50° F. aver.

200-12-17. Form G 113

FIG. 44.—MAINTENANCE RECORD CARD

Individual cards are kept for each piece of equipment. Front side of the card contains data of identification, sometimes sketch and references to drawings, catalogs, alterations made, etc. Reverse side is shown in Fig. 45.

of the operating engineers formerly believing that their past experience (without minute record) warranted them in making certain conclusions and express preferences in matters of purchase of supplies and materials. As regards the modification of design in compliance with the repair records, the author recalls a case of a large railway central station having excessive repairs on a condenser due to poor water and electrolysis. An emergency repair was made by using concrete to mend the casting eaten away; the results were excellent and the concrete division wall stood several years of service. A recommendation was also made to the builders to change their design by using replaceable partitions in case they are worn

out instead of replacing the entire cast-iron base of the condenser. Economically the results were highly gratifying.

Emphasis was laid in the last chapter on the importance of careful selection of materials and fitting of equipment for the service; far greater importance must be attached however to the men whose work consist in keeping the plant in a condition that permits the actual full utilization of the plants ultimate or inherent efficiency. A successful mastering of material side of a power plant calls for more than first-class mechanics engaged in its upkeep—it presupposes a clear comprehension by the management of its uppermost duty: *To base orders on facts.*

Cooperation Between Operating and Maintenance Forces

In carrying out the maintenance work to its successful end one fact becomes clear—there is a very close relation between operating functions and care of maintenance. It may be said without exaggeration that the success of the entire enterprise largely depends on the spirit of coöperation which the maintenance force shows toward the operating departments. Good maintenance, as we have shown, is not only repairing of breakdowns nor even merely preventing loss of efficiency and interruptions in operation, though both are parts of the task, *the aim of maintenance is to care for the physical conditions within the plan thus permitting the operation to be carried on with minimum exertion on the part of the men and maximum efficiency on the part of the machines.* That it spells economy needs but little proof. In a small glassine-paper mill poor physical condition of the power plant caused not only an extra $16,000 to be needlessly expended on fuel and $10,000 on repair of equipment, but it caused loss of production amounting to $70,000 for 30 days during one year. Such examples may be multiplied endlessly but the point is that no plant is too small to introduce and carry a complete program of maintenance work.

Effect of poor maintenance on thermal efficiency of the plant is well known and has been previously discussed. It must be pointed out now in this connection that purely physical deterioration of efficiency of equipment is only one factor in the total drop of economy in a poorly maintained plant. The psychologic influence of neglected upkeep, uncomfortable surrounding, inconvenient or even unsafe working conditions, etc., are unquestionably of no lesser importance. No man likes to work in dirty, noisy, unsightly surroundings. Even pigs do not like dirt and are more successfully

REPAIR RECORD

Date Out	Days & Hours Out of Service	NATURE OF REPAIR	COST		
			Labor	Material	Total
12/28 1914	10 Days	Out change Water, inspect internally. Brackit Valves cleaned, repacked. #1, 2, 3, & 9 blow-off valves repacked #4 replaced by repaired old	15.80	5.24	21.04
2/26 1915	33 days	Inspected by McGowan Co. M.C. Co. on 3-11-15 : Main steam drum & mud drum cleaned, Tubes polished cut in 3-31-15	24.10	1.98	26.08
6-1	12 d.	Change water, insp. Tubes combustion removed Water column overhauled #3 & #7 blow down Valves removed. Drum cleaned Cut in 6-13-15	12.20	34.40	46.60
8-24	7 days	Change water, inspect tubes. combustion removed Tubes expanded #1 - 1st row - 2nd unit #1-2 & 3 - 1 row - 3rd unit #1-2 - 2nd row - 3rd unit Cut in 9-1-15	9.57	3.49	13.06
10.15	8 d.	Order 8-19	7.46	2.48	9.94
12-20	7 d.	Order 8-19	8.34	3.05	11.39
		Annual Cost			128.11
		Idle Charge 67 days			21.40
		Total			$149.51

FIG. 45.—MAINTENANCE RECORD CARD—REVERSE SIDE

Record of repairs made are entered from data collected on form Fig. 43. It represents the history of individual piece of equipment.

bred in sanitary conditions, yet many plant owners shrink before the responsibility of maintaining their plants in condition that would bring out in their attendants the feeling of pride and interest. The efficiency of our Navy is in a large degree traceable to the cleanliness and first-class maintenance of equipment and surrounding; if maintenance were neglected, the Navy would soon break down. Similar losses to production and general welfare of industries and communities are not widely known and fully appreciated but, whenever data are available, they leave no doubt that every dollar spent for perfect maintenance saves a twenty dollar loss. Again, the much talked of loss due to excessive turn-over of the employees in many cases is caused by poor maintenance of plants making work repulsive to the best men, while perhaps only the men of lowest intelligence stay and endure. A plant under our observation that has neglected maintenance of boiler house for years degraded in course of comparatively short time to the point that its efficiency instead of being 70-72 per cent, as it should, dropped to 47 per cent and in spite of higher wages offered to the men than prevailing in the neighborhood, the turn-over was above 300 per cent and engineers had to resort to hiring negroes, until finally, at a large expense the maintenance work was caught up, 73 per cent efficiency on the average realized, and men became contented.

Chapter VI

MASTERING LABOR PROBLEMS

ANY change in the economic life of a country by necessity readjusts the social relations of productive forces. These new relations, reshaped primarily to meet the new conditions and requirements the material life, gradually change the habits of the people, the mode of thinking and finally formulate new ideals. Roman domination of the Ancient World at first created and then eradicated distinctions between "Ellin and Jew" and lust for domination. When the efficiency of wage earners compared favorably with slave labor, the new relation found its expression in the formula "Liberty, Equality, Fraternity." When again, the socially irresponsible control of production failed to meet the demands for higher production, the industrial democracy became the new ideal. No sooner the old order of things gives way to the new one but when the old mode of production has already developed all its possibilities and the new way appears clear, leading away from the vicious circle of old internal contradictions.

The great conflict between autocracy and democracy has more than political significance. The principle of "government for the people and by the people," awaits its application within the economic relations of the people since it is more and more generally conceived that the ignorant and irresponsible control of production causes waste and leads to destruction. The alleged supremacy of autocratic government either of nations or of industries is a fallacy created by the confusion of parts with the whole. The relative advantage of Teutonic imperialism was in the recognition and thorough application of *the principle of coördination of action and strict accountability for results,* and not in its arbitrary absolutism. Whenever the people themselves exercise the right of judging the results and actually choose their own leaders, there is obviously little opportunity to substitute the ideal of oppression for this of mutual benefit.

What it seems to be correct in respect to nations is equally true in the industries. The success of great industrial leaders

and managers was in the final count due to the adoption of superior forms of organization weherein the thorough knowledge of facts takes the place of ignorance, and coöperation supersedes the competition.

It is obvious that without a thorough knowledge of the facts pertaining to all functions involved in production, the possibilities may not be fully recognized. Moreover, full advantage of facilities, materials and knowledge cannot be realized unless there is a full coöperation striving at the attainment of the highest aim. Hence the emphasis was laid in the foregoing chapters on the importance of full familiarity with the elements entering into a problem of power production; *the all important of these is the human element or labor.*

Autonomous Coöperation

To carry out such a program, a fitting mechanism is to be developed. Taylor's functional foremanship offered a logical and promising step in this direction, yet its intrinsic limitations retarded its wide applications. Managerial functions centered in the planning department give a strong autocratic smack to its "ukases." Democratic spirit of coöperation was sacrificed to that of oligarchy by official bossdom; the routine of administrative control became by necessity complicated and perhaps cumbersome; and finally the success or failure of the enterprise so organized hinged on the spirit of the man at the top. So it was with the Kaiser—were he animated with the ideals of humanity, the Germanic thoroughness would perhaps have been bent on beneficial constructive work instead of on destructive.

Such is the inevitable trap into which the individualistic cult of "hero" or "leader" or of "superman"—falls: competitive development of means of oppression cannot last when the base begins to shake, and the one on top has to tumble down.

Ganttism, if the author may be permitted to introduce this term to denote the new conception in industrial philosophy, concieves the wholesomeness of autonomous self-government of shops. The success of each contributes to the success of the whole since the lowering of quantity or quality of the product by one, affects the rest unfavorably. Broadening this viewpoint to the boundaries of the whole industry, we can see equally plainly the advantages of coöperation over competition; spreading this conception to cover economic relations the world over

we get the lofty ideal of the mutuality of interests of all nations similar to this of all shops of a factory, or all the states of a union after the protective inter-state tariff ceased to serve as a means of economic holding down.

The author has advocated for many years the importance of recognition of the autonomy of the power production department in the industrial organizations as well as in public utilities and it should be obvious to any unprejudiced mind that a general planning department, however perfectly organized and smoothly running and still less old-type "general" management is incapable of wisely directing the peculiar functions of power department unless it has in its staff power specialists to devise, direct and supervise the specific functions. When this is the case the removing of such specialists from the close living contact with the department they are to direct and placing them into an office whose functions are specific and distinct, is void of practical advantages. The close coöperation between the manufacturing departments and the power department in factory, or between the power production department and other departments of a public utility is of great importance both for the purpose of ascertaining the extent of demands, regulating peaks, etc., and for securing materials as well as coördinating other functions of mutual importance.

Mr. J. P. Frey in his critique of the Taylor system of management said, "it is unscientific because it has failed adequately to understand the human factor and the spirit of our American institutions for it makes of one man a task-maker and a task-master without consent of the other." Government of a plant should be like the government in a state, *with the consent of the governed.* Yet if the political selfgovernment is acquired by the ignorant people failing to set a wise policy, devoid of far-sighted program and prompted in their actions by a desire to get immediate advantages without thorough consideration of ultimate results, they fall an easy prey to neighboring states if they are strongly organized and aggressively inclined. Similarly, in the case of an industrial establishment, the self-government or management by consent should be preceded by a broad and thorough educational work, enlightening those actively engaged in production on the matters contributing to the fundamental success beneficial first to the establishment and ultimately to the community.

Shop committees and similar forms of representation of labor

interests in the problems that heretofore have been considered a sacred prerogative of board of directors and of management are gradually gaining popularity. President Wilson in his speech of May 20th said that the "genuine democratization of industry, based upon a full recognition of the right of those who work, in whatever rank, to participate in some organic way in every decision which directly affects their welfare in the part they are to play in industry."

In the problems of such complexity and importance as management of public utilities, railroads or industrial plants, numerous purely technical as well as difficult economic problems must be studied, analyzed and presented, before any decision or settlement of a controversy may be reached. Mere compromise, by its very nature can satisfy neither party for a compromise is something that neither party wanted. While many workingmen know the shop conditions better than some managers, they often lack special or broad knowledge that is indispensable for fair and convincing presentation of facts; again lack of certain knowledge essential for the settlement of a dispute occasionally leads labor to present demands detrimental to themselves. It was the French engineer Le Chatelier who recalled his experience with miners who complained against certain settlement which in fact was far more detrimental to the employers than to employees.[59] One of the author's own experiences has been that a shop committee failed to obtain the owner's consent to install certain safety device because they stated a cost of installation prohibitive in price while in reality the cost was less than one-tenth the figure.

For such and similar reasons the workmen are more and more inclined to trust their cases to either union officials or to attorneys-at-law. Unfortunately neither is fully qualified to deal with engineering, managerial and economic problems involved and so difficulties and discontent results, which usually works to mutual disadvantage.

The major part of the cases coming under the jurisdiction of shop committees and causing industrial disputes call for men that are qualified:

1 To investigate working conditions and processes and their effect on workmen and their productivity or efficiency

2 To look into safety, hygiene and similar factors affecting the work

3 To study the questions of hours and payments

4 To analyze the basic causes of grievances or discomfort and report on means of elimination of the causes

5 To secure data and facts showing the effects of objectionable features and prepare estimates of results of modified practice, showing advantages and expenses, if any, of satisfying the demands

6 To represent the facts before committees on arbitration, in courts, before the congress, etc.

No other professional man is better fitted to fulfill this task than the engineer, and it is to be regretted that labor, probably due to mistrust, does not employ engineers as it does experts of the medical and legal profession. Apparently, labor organizations are not quite awakened as yet to the still greater necessity of submitting special matters to investigations and studies by specifically trained engineers. The problems involved in setting tasks for power-plant employees, for instance, cannot be settled by mere debating and discussion of opinions.[60] The underlying facts of industrial life cannot be obtained without a great deal of scientific research work, and to establish beyond doubt their veracity and fairness, or to expose the contrary, requires a great deal of expert knowledge and intimate familiarity with the subject. Medical treatment is not decided by popular vote—why shall the health and happiness of wage earners be left to similarly arbitrary method? To avoid any possible misunderstanding on this point, the author must emphasize the fact that, while the consent of labor is an indispensable pre-requisite for the success of any industrial readjustment (be it methods, equipment, relations, etc.) this consent cannot be attained by an arbitrary decision based on opinion and prejudice. It must be based on facts, indisputably established by a trustworthy research.[61]

Our social relations are now approaching the stage when military discipline is unthinkable in the shops and power plants. The men want to do things in the right way but time and again it has been demonstrated that labor will not submit to arbitrary rule particularly if it comes from incompetent quarters. Again, in the power industry, where every process and every operation

is clearly defined by unrepealable laws of nature, there is neither room nor excuse for any form of management but that based upon these laws. We need no lawyers or courts to support the laws of gravitation or chemical affinity, or electrical phenomena. The management system, mastering the production in accordance with similar elemental laws, needs no other force for backing but to make public the knowledge of facts.

In the author's address before the Taylor Society at its annual meeting in 1916, he touched upon the subject: "the advocates of strict military discipline are apt to imagine that the new habits can be forced on the men by fear of dismissal or milder disciplinary measures. This may work as long as the men do not see their way out of the pressure, which usually does not take very long; then the new-comers must be forced into the regime at a great expense of time and energy. Meanwhile an elaborate system of espionage, bossism and pressure must be brought into play if the rule is really to be enforced, otherwise the things are done in the prescribed manner only while men are under surveillance, or more often it only appears so to the casual observers and to the imagination of the advocates of big stick rule."

The obvious advantages of this policy of leading and teaching over that of driving and forcing are:

1 Less effort is needed to lead than to push

2 Voluntary actions are performed even when not watched; a correct method is convincing and, when correct habit is formed, the best results follow necessarily and remain permanently

3 The coöperative spirit is developed rapidly and from within thus insuring its perpetuation

4 The expense of study, training and bonus are covered by a fraction of savings accomplished whereas the expense of coercion, forcing and overseeing is not.

We do not need to shut our eyes to the fact that antagonism of interests between employer and employee exists and the Utopia of harmonious relations between these two classes will remain such until both are absorbed in a new social group. The signs of the times are many and they point to the fact that public utilities are to be steadily and gradually nationalized. The same is true regarding other branches of in-

dustries and this is evident in all countries of the world. Moreover, it is no longer disputed that the principle of "service to the people first" yields larger returns than the old motto: "the public be damned." The task of an engineer called to master production is that of producing things with the minimum expense of time, energy and material. So long as he is bent over this task, the public at large demands that the industries shall be democratised. Democracy in the industry means production carried out for the benefit of the community. This change of relations brings us back to the fact that the community demands the right to say what is and what is not to their benefit. A predominating majority of any community consisting of producers (who at the same time are also consumers) is rapidly making itself heard. "Democracy in government, democracy in industry, democracy in education"—such seems to be the new password.

Aims of Labor

While German Kultur and Allied Civilization were locked in the deathly grip of their fight to the finish, a detached observer[62] watching the conflict from the opposite hemisphere declared it to be nothing less than the end of the old European civilization. There might be a wide divergence of opinions regarding this estimation of the event, but numerous facts prove beyond any doubt that most of our fundamental conceptions were brought into disrepute and definitely shattered. If what we call civilization was based on the conceptions of special privilege for few and arbitrary rulings of masses, it lost the foundation and whatever the constructive (or reconstructive) task is ahead of us, it should be carried from the bottom up.

Ancient civilization was based on the institution of slavery; Plato, Aristotle and Xenophon considered that the citizens of their republics should live in most complete leisure, since, as the latter has said, "Work takes all the time and with it one has no leisure for the republic and his friends"; similarly Lycurgus forbade the Spartans to have any trade. With the development of modern machinery, slavery was dispensed with, as unnecessary and inefficient, and to-day one horsepower does the work of twenty slaves. Private ownership of means of production and employment of wage-workers became a characteristic institution of capitalist era. During the war this private ownership failed to meet the requirements popularly demanded and one

by one great industrial undertakings were taken from private control and placed at the service of a nation or even nations. Such was the fate of shipping, of railways and of other means of communications. Then came an encroachment on the time-honored individualistic competition; prices and outputs were controlled or regulated according to the common needs. Co-operation was hailed and competition frowned upon; profiteering condemned and public service praised. Ability to produce things commanded credit while mere ownership was heavily taxed; work became respectable and idleness ranked with treason. ("Idle hands assist the enemy"—war poster.)

These changes were neither local nor casual—they were universal and necessary for otherwise the acclaimed purpose of making the World safe for Democracy could not have been accomplished. The wage earners could not overlook them and notice was taken that steps in this direction are indispensable for the common good. Moreover, financing of war, of industries, of feeding starved countries was not carried out by a group of financiers—it was accomplished by popular subscriptions, by thrift-stamps, by collections of pennies in public schools. Thoughts and feelings of masses were radically changed. They realized that they have the power to do and undo the thrones, the wealth, the future. The dissolution of old conceptions was thus made complete and the new order of society loomed on the horizon. We may not, as yet, be able to see its forms, but one must be totally blind not to see that new industrial relations are being formed in which labor takes a far more important part than it ever heretofore enjoyed.

Moreover, the much abused statement that "labor and capital are partners" and "the coöperation of both is essential for the happiness of either," became stale and, in some quarters, a laughing stock. The enormous production and consumption of war materials was not expected to last long as sufficient capital was not available; yet the productive labor accomplished what was thought impossible, thus proving that capital is neither essential nor a desirable partner of labor.[63] Again, while it is indisputable that capital, as represented by machinery and other means of production, is indispensable for application of labor, the ownership of means of production need not necessarily be entrusted to only one side of the partnership; indeed state ownership and governmental control of some most essential properties proved to the people in general and the working

class in particular that the control of means of production, of transportation and of natural resources can be operated more satisfactorily if "partnership" of capital and labor is displaced by public or government holding of these means of production.

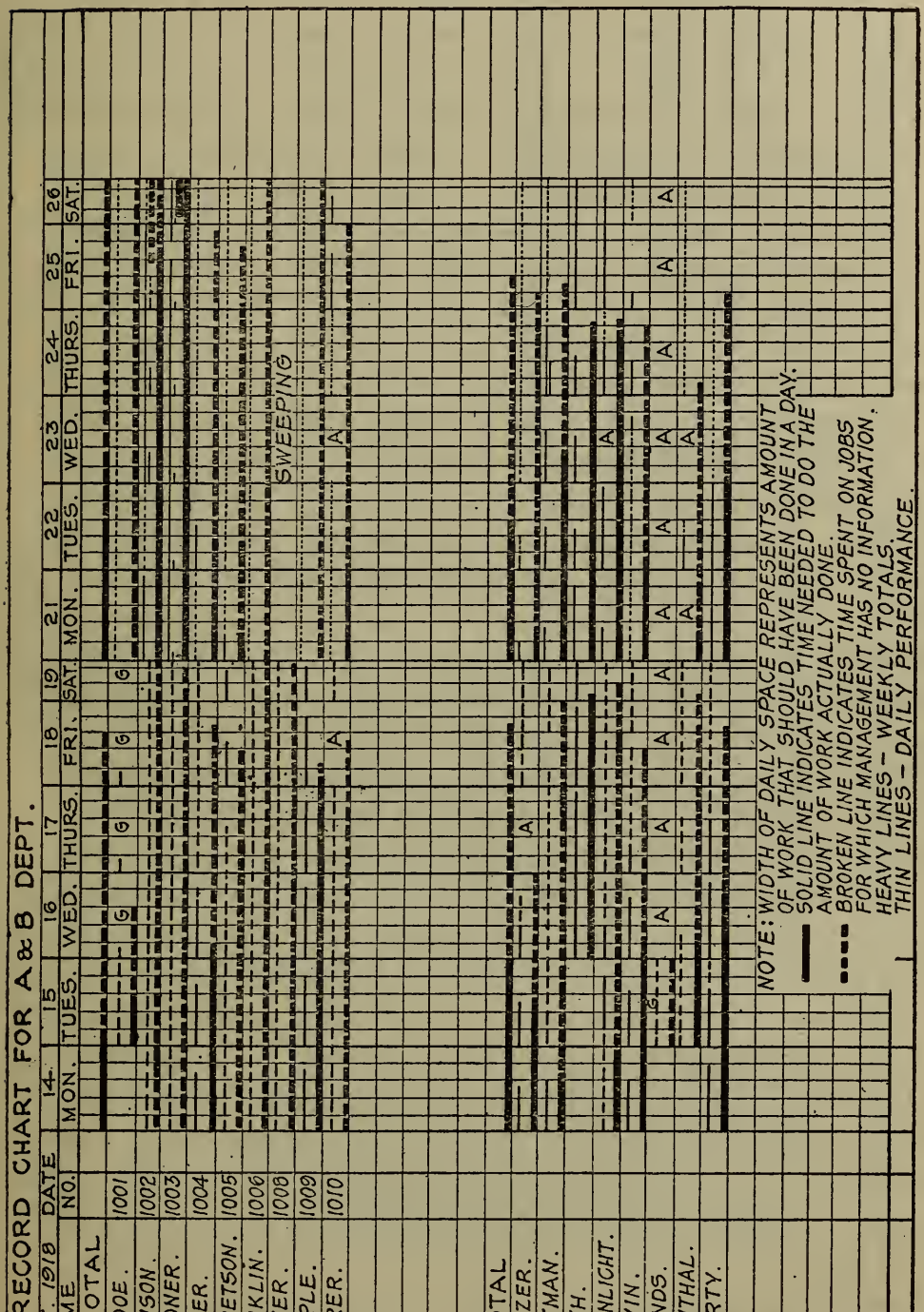


FIG. 46.—MANAGEMENT RECORD CHART

Chart showing known and unknown length of time required to do the work. Broken lines visualize the time consumed on jobs for which management had no information as to how long it should take to finish the work. Letter *A* denotes operator absent; *G*—green operator. (Courtesy of H. L. Gantt.)

Such and similar every day occurrences and observations during four years of war could not but completely change some of the old fundamental conceptions and the aims of labor were reshaped accordingly. While in the countries that suffered most from the effects of the war the communist ideals sprung out and were partly realized, more conservative labor elements as may be exemplified by The British Labor Party made a detailed reconstruction proposal[64] in which it stands for "a great bound onwards in aggregate productivity." This, it explains, "cannot be secured merely by pressing the manual workers to do more strenuous toil, or even by encouraging the captains of industry to a less wasteful organization of their various enterprises on a profit making basis. What the Labor Party looks to is a genuinely scientific reorganization of the nation, as industry, on the basis of the common ownership of the means of production; the equitable sharing of the proceeds among all who participate in any capacity and only among these, and the adoption, in particular services and occupations, of those systems and methods of administration and control that may be found, in practice, best to promote, not profiteering, but the public interest."

The signs are many and unmistakable that labor will claim an increasing share in the management and control of the industries and plants, and to accomplish that end will seek any opportunity to learn, advance, promote and apply such systems of scientific mastering of production that help to carry the production for the benefit of the community. Instead of supporting waste and mismanagement and opposing economy in efforts and use of materials as before, organized labor demands more scientific and more humane methods of industrial administration. Professor Person, president of the Taylor Society, brings out a few interesting examples of this tendency: " . . . an order was issued by Clemenceau directing in considerable detail how the Taylor principles should be applied to the organization and administration . . . 'to secure economy of labor and of mobilized personnel.' It ends with this significant sentence: '(The present circular) should not be taken as the last word in the organization of work but as a beginning towards more and more efficacious and scientific methods.' In discussing the urgent problems of the Soviet rule, Lenine says that the necessity of Soviet administration has been recognized by the Russian people. . . It de-

mands a conscious mass movement towards a higher productivity of labor in comparison with capitalism. . . . "

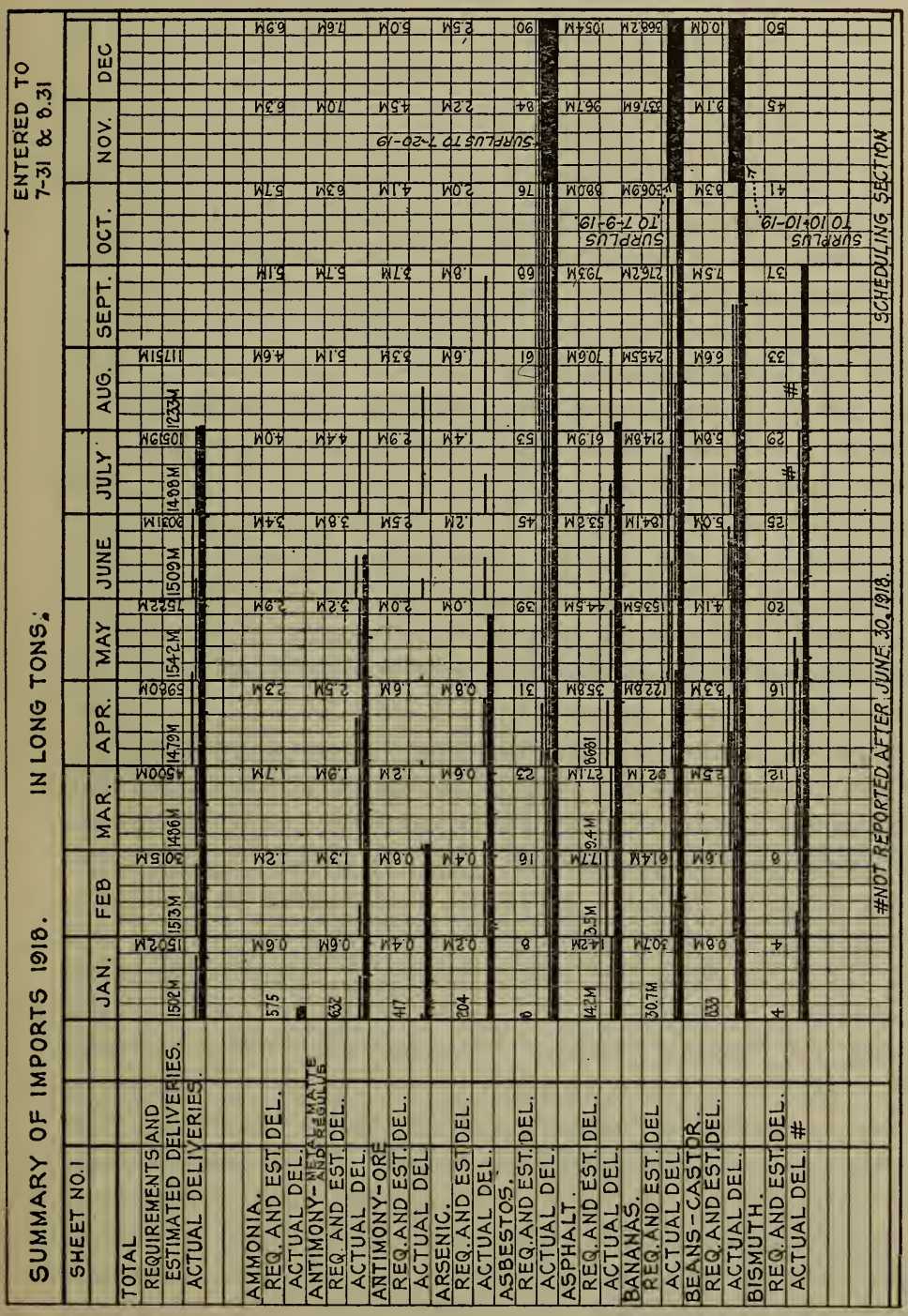


FIG. 47.—CHART OF REQUIREMENTS AND DELIVERIES

Estimated requirements for each month are represented by 100% scale of monthly space. Figures written horizontally show demand per month and vertically estimated delivery to date. Lines are drawn on percentage and time scale showing shortage or excess of actual deliveries. On this chart shortage of ammonia is appalling while oversupply of bananas led to their destruction.

The Socialist Party in the United States like the British Labor Party believes that the people will not tolerate "any reconstruction or perpetuation of the disorganization, waste and inefficiency" which heretofore flourished in the industry. As one

of the first steps, the Congressional Platform states the following aim: "*Power.* The coördination of coal mines, water power and the generation of electricity under national ownership and control has already been proposed by the English Ministry of Reconstruction as the only possible policy for the British nation. The establishment of immense super-power electrical plants in the vicinity of mines and waterfalls for the purpose of supplying current to large areas of consumers, including the railroads, offers unparalleled advantages in economy and efficiency of public service and the prevention of fuel famine. By such system the cost of electricity could be so reduced and the service so extended that every household in the nation as well as every industrial establishment and farm could be supplied with electrical energy at almost incredibly low rates. This is the inevitable future of electricity. The Socialist Party demands the immediate appointment of a Federal Power Commission with adequate representation of labor to make an exhaustive investigation into this subject and to recommend legislation to Congress which will embody a comprehensive power development policy, as well as proposals for the immediate nationalization of the coal mines and the reclamation and conservation of all the great sources of water power."

Perhaps the most significant statement which shows the attitude of the working masses toward increased productivity may be found in the report of joint conference of British Industrial Council for the Building Industry. This "*Organized Public Service* in the Building Industry appointed a committee in February, 1919, consisting of eight employers and eight operatives and adopted (1) 'This committee was appointed to consider the question of scientific management and reduction of costs with a view of enabling the building industry to *render most efficient service* possible.' (5) 'We believe that the great task of our Industrial Council is to develop an *entirely new system* of Industrial control by the members of the Industry itself.' (7) It became clear at very early stage that there are four main factors that tend to the restriction of output. They are: a—The fear of unemployment; b—The disinclination of the operatives to make unrestricted profit for private employers; c—The lack of interest in the Industry evidenced by operatives owing to their non-participation in control; d—Inefficiency, both managerial and operative. (34) Hiring of capital. It will already have become evident that the *whole conception of organized public service*

that we are developing demands the acceptance of these main principles as an essential preliminary to that *increase of efficiency without which the cost to the community can not be reduced.* a—Regular rates of pay to the operatives that will insure a real and satisfactory standard of comfort; b—Salaries to owner-managers commensurate with their ability; c—A regular rate of interest for the hire of capital. (54) The consensus of the evidence led us to the following additional recommendations: a—That there should be more inducement to the most talented operatives

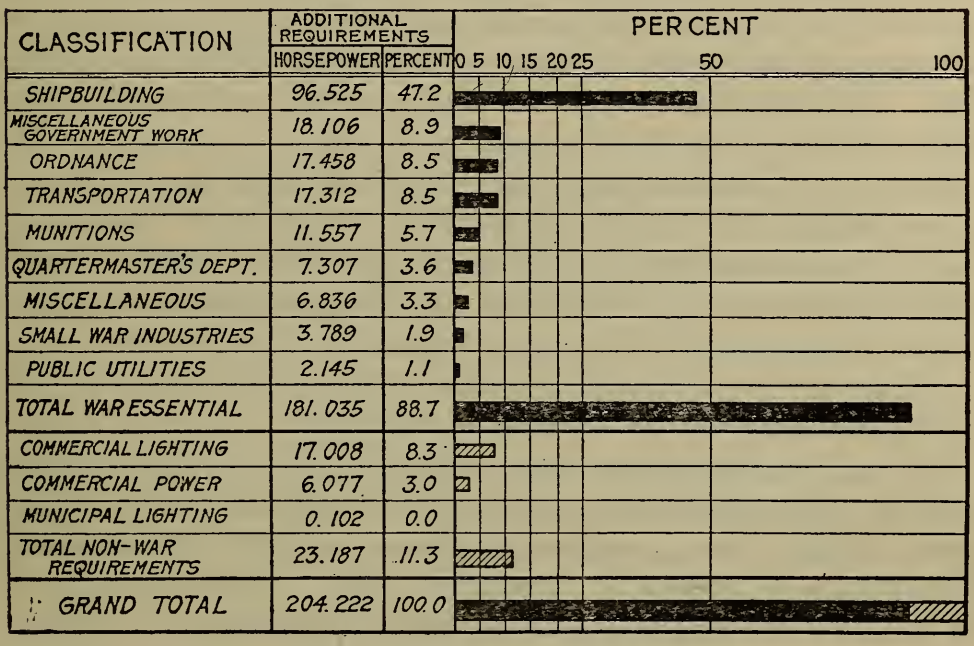


FIG. 48.—POWER REQUIREMENTS AND AVAILABLE GENERATING CAPACITY

A graphic analysis of a study made during the war for U. S. Shipping Board to ascertain the needs of a district.

to increase their efficiency and to undertake positions of greater responsibility; e—A better output will be obtained if the personal comfort of the operatives is provided for. . . "

The quotations we put in italics ourselves.

Similarly the United Mine Workers of America declared their aim at the 27th Convention at Cleveland, O., in these words: "We hold that the coal supply of our nation should be owned by the commonwealth and operated in the interest of and for the use and comfort of all the people of the commonwealth. Countless generations of men and women will doubtless follow us, and the American people of this generation owe a solemn duty to them in protecting with jealous care and *conserving with wise administration* those great treasures that a

bounteous nature has bestowed upon us in such generous measure." "Under the prevailing system of private ownership, coal is mined primarily for the purpose of creating profits for the coal owners. The production of coal under this system is characterized by an appalling economic waste. The incomparable natural resources of America, and particularly those of timber and coal, are being despoiled under a system of production which wastes from 33 to 50 per cent of these resources in order that the maximum amount of dividends may accrue to those capitalists who have secured ownership of these indispensable commodities." "Under private ownership, where production is conducted for private gain, the spirit of times seems to be: 'After us the Deluge.' This must be supplanted by a system where *production will be for use and the common good, and economic waste will give way to conservation of the nation's heritage in the interest of posterity.*" "We, the United Mine Workers of America, in international convention assembled, representing the workers who have their lives, and the welfare of the dependents *invested* in the coal mines of our country do therefore resolve:

"That we demand the immediate nationalization of the coal mining industry of the United States."

To understand better the attitude of American workers toward mismanagement and waste in industry and to gain better insight into growing aspirations and aims the foregoing citations are of help.

Recently the employees at the Rock Island arsenal have improved managerial methods and thereby increased the productivity and reduced waste and needless expenses.

Right to Be Lazy and the Right to a Job

A French writer published in the early eighties under the title, "The Right to Be Lazy," a sarcastic pamphlet directed against the philosophy teaching the producer to reduce his demands to the smallest number of needs, to suppress his joys and to condemn him to play the part of a machine turning out work without respite and without thanks. In more recent times, the so-called efficiency engineers and even Dr. Taylor attracted the wrath of organized labor, the latter receiving the surname of "speedy Taylor," for his propaganda of religion of work. It is not our task however to review the history of this misconception. Since the time Genesis was written work has been regarded

as a curse and damnation brought about by sin. The sophistry trying to prove that work is a pleasure fails to convince anyone who works for hire, works long hours, works under trying conditions, works to nervous and physical exhaustion, works at something lacking the inspiration of self-expression or at work which fails to produce the joy of converting knowledge into action. A plain unsophisticated mind of a sane person revolts at the idea that we "live to work" while the plain truth is that "we work to live." The greatest advent of civilization was the reduction of the working hours allowing the masses more time to live, to learn, to improve, and this was accomplished by engineers. The wonderful creation of engineering science and art increased the productivity of a man to almost an unbelievable extent. The power-driven automatic and semi-automatic machinery and means of transporting their product to the places of consumption relieved the men from an enormous share of physical labor formerly required and enormously reduced the time needed for production and transportation. A measure of increased productivity of labor may be gathered by considering the large and increasing number of non-producers, salesmen, advertising men, bankers, lawyers, soldiers, etc., who are consumers only. The future progress of engineering is hard to foretell but it is being daily demonstrated that even with our existing means of production vastly more can be produced than now because of poor managerial methods, idle machinery, imperfect processes and inadequate knowledge of what is being done, how it is to be done and what could have been done if the various obstacles were removed. In the estimation of H. L. Gantt the industries at present are producing about one-quarter of what they are really capable of under proper administration. If this is so, with the same number of workers employed they could produce four times as much goods in the same time or, greatly reduce the length of the working day without reducing production. In this sense, the right to be lazy, like any right, involves a responsibility to see that:

1 The work is organized and carried as productively and efficiently as the state of science and art permits
2 That the work shall be as safe and agreeable as possible
3 That it overtax none.

Such is the task of to-day before industrial engineer, yet the workmen are often assailed will fear lest the increased

productivity will leave to him nothing but an enforced leisure and thus no means for existence, for as the Bible said: "He who will not work, neither shall he eat." Hence the "right to a job" is the right to live. The study of the history of industrial development taught us that every improvement, either in machines or methods that increased productivity, stimulated the consumption of goods to such an extent that a much larger number of men find employment in the industry thus developed. Yet while this is true, it is equally true that this adjustment takes a certain length of time during which the number of men employed in the industry thus affected, temporarily drops. The question then arises: how is this contingency to be met? Under an ideal condition, (i. e., when production is carried not for speculation but for common good and for use) the matter may be easily regulated, as it is possible to gage the demand. If in this manner the extent of the demand is established either for any kind of commodity and the productive capacity of the plants is known, the amount of necessary labor is thereby ascertained. The same procedure would furthermore indicate where more men are needed and where there is an excess of unemployed labor; in some localities larger production of a certain article may be needed, while in some other it may be reduced or even discontinued as superfluous, thus plants and men may be turned to other purposes. Under the present social conditions men seek employment primarily because of necessity of earning the wages offered, and everything else is regarded by them as merely contributing or damaging incidents. Vocational training is still in its infancy so far as power-house help is concerned. Organization for supplying trained help, in order to become an effective factor must be nation-wide in its activities and its scope of work should embrace the daily gathering of information from the entire country as to men and jobs available, wage fluctuations, cost of living and conditions in various localities and industries. On the basis of these facts the machinery must be able to quickly shift surplus men from one state to another to a place where there is a need for them, having transportation and accommodations prepared and provided beforehand to the volunteers. By an elaboration of such a plan as has been tried by German labor unions, the problems of unemployment, inadequate wages, poor working conditions, etc., may be successfully ameliorated. The crowning success of such organization would be the classifi-

cation of all available men according to their inclinations and fitness, so as to intelligently meet the specifications for the industrial positions.

In the summer of 1918 the Department of Dilution and Training of the Labor Department asked the writer to submit to them a memorandum on the subject of meeting the shortage of skilled workmen and the outline of the working plan as furnished is substantially as follows:

"A proof of the necessity of either training or dilution of labor should be secured before either is attempted. The general warning is given when a productive organization falls short of its promises or specifications either in quality or product or in the time of delivery. This may or may not be the result of the labor situation, since it is part of the labor to follow the plans provided by the management in using materials and equipment furnished by the management. The first step therefore should be to ascertain whether the industrial establishment experiencing difficulty is actually using its productive equipment full time.

"(1) In cases where the equipment is idle because of lack of orders, lack of materials, poor materials, poor machinery, poor maintenance or poor planning, no extra labor, whether trained or unskilled would do any good, in fact, it would cause further labor shortage elsewhere in the country.

"(2) In cases where the cause of idleness of equipment is allocated to the lack of help, the trade and degree of skill required could easily be established and the Department should assist *only* when proof is given that the troubles of the first category are non-existent. Otherwise no labor should be allotted to an establishment where working time will be lost due to unpreparedness of the management to use labor productively. . . .

"These informations may be secured by obtaining from the concern experiencing a difficulty, presumably on account of labor shortage, the graphic reports analyzing time of every machine, and showing how much time was spent working and how much time idle, waiting for jobs, etc. . . .

"Our experience taught us that more often, the inefficiency of a concern is due to faulty management than to inefficient labor. The walk-out at Cramp & Sons and similar occurrences are typical instances where working men are first to protest against the handicaps created by incompetent leaders of any rank.

"Accepting the foregoing as a basis, the mechanism, to carry out the program, can be developed following the principle of allocating the trouble first and then *trying to eliminate the inefficiency before attempting to increase such efficiency as we already have.* Charting method seems to be admirably fitting for the purpose. It is simple, reliable, readily understood by any and all and involves minimum expenses for introduction and keeping up and has been thoroughly tested for a long time in many private industrial establishments and Governmental productive organizations. . . .

"The time-keeping department or the production department of any factory or mill should be able, without extra expense, to prepare charts showing useful utilization of men's time, once they admit the principle that the object of time-keeping is not merely to find out how much is to be paid for the total time but *what has been done* during this time and *what should have been done* during this time, as well. Figure 46 illustrates a characteristic case of a shop where management has knowledge of what could be done and what was done by men during the working time.

"One of the possible objections on the part of some manufacturing establishments, as may be anticipated, is that 'it won't work in their particular case.' We do not doubt, for a minute, but that there are such cases where the existing management is unable to secure the desired information and these points should not be debated. The task of the Labor Department should be to assist the management in establishing such simple means as necessary for securing the desired information . . .

". . . Preparedness for the time when we must fill our new cargo space, not with war munitions, but with manufactures (if we do not want to go back to exporting our raw materials and the buying it back again worked abroad into high-valued product) is of immense importance and nothing less than quick adjustment of labor and industries can avert the confusion and chaos of reconverting the industry from war to peace footing . . ."

We are now facing the opposite side of the problem. Under the untrammeled "free bargain," the workman refusing to accept the wage offer or working condition was free to either change his mind and, if the employer has not changed his, to get the employment or—perish. The unemployed, like the poor, were with us for so long a time that we grew accustomed to consider them necessary for our salvation. This reserve labor army had to perform a dual manoevre: to lower the wage rate by competition in case of supply exceeding

the labor demand and by expansion and contraction to relieve the industrial payroll in days of depression and to furnish dividend-grinders in days of boom. To-day, with the probability of unemployed lending an eager ear to the propaganda of extremists, the conservative employers begin to think whether the unemployed will not really be instrumental for their reaching Paradise.

During the War an acute shortage of help in some power plants prompted some public utility companies to hire as firemen, the street cleaners dismissed by municipalities for inefficiency; the unemployed were rare but those employed, began to think along somewhat new lines: *"If my employer has right to his property as it gives him his income, have I not right to my job which is my only source of income?"* In the past, this right of workman to have a job was light-heartedly denied principally because no means were known how to provide work all the time for everybody in the industry conducted on the principle of unrestricted individual competition. Under such conditions, the amount of commodities that should be produced were not known; at one time less men would be engaged; then the possibility to sell goods at high price would create a rush and, as limit of demand was not known and some mnaufacturers possibly did not know how much of the same goods their competitors produce, the oversupply will ensue; in order to check the falling of market prices due to people's inability to buy these goods the production slowed down, *i. e.,* men were laid off. In this general manner, the periods of more acute unemployment follow one after another in an utterly unregulated way. Again, local condition may favor rapid production in one locality, while depression even possibly in the same trade will reign in another at the same time, yet migration of labor was left chiefly to a chance, hearsay information, individual resourcefulness and other haphazard circumstances.

True enough, power industry was subject to these fluctuations to a lesser degree than some other branches but it is felt nevertheless in public utility plants and mill power houses whenever the demand drops due to increased number of idle machines or whole establishments. It is true also that due to the character of the work in a power plant a certain number of employees will be steadily employed whether the load is heavy or drops to a small fraction of the normal, but in any event the fluctuation of employment and a chance for employee to lose his job, in time when it is hardest to get another, does exist in this industry to an appreciable extent.

During the war, the United States Shipping Board carried out an intensely interesting experiment which is of enormous value.

Data collected for supply of various commodities were compared with estimated monthly demands for the same and results plotted by Gantt's charting method (see Figure 47). Now, suppose that the curve represents not imports but domestic production; if we see as clearly as on this chart that the rate at which certain commodities are manufactured are many times in excess of requirements while other hardly meet the demand, it may be comparatively an easy task to stimulate one and slow down another until the healthy balance is established; thus a constant number of workers will be assured of permanent employment. This is equally true regarding the power industry and relations between the demands and resources. Figure 48 represents the demand in excess of generating capacity, showing percentage of full output analysed by groups of consumers.

Unfortunately most of the well-meaning social reformers and friends of labor are not in a habit of scientifically analyzing the facts and to look for solution at the cause of the problem. Their customary panacea for unemployment is not along economic facts but in compulsory legislative orders to provide work by artificially creating it at public expense. It might be that we need new houses, new roads, new hydroelectric plants—if these public works are socially necessary they should be carried out whether there is enough employment or unemployment, in latter case of course the sooner the better—but one must see that the men engaged in the project are skillful, experienced, and possess the ability and ambition. The digging of a canal will probably indirectly help the unemployed milliner or seamstress or engraver, but the demand for the goods they produce could be increased by some other means, and if the public work thus undertaken is performed inefficiently because of unfit men engaged, the expense of the undertaking is liable to be greater than the benefit therefrom and it might have been wiser to spend less money directly as premiums on unemployment insurance. On the other hand, when production in various industries loses its anarchic, uncertain character and is carried out to the fullest extent warranted by the consuming capacity of the people, the same very public work project will be carried out not as a charitable undertaking but as an economic necessity growing out of the natural general development.

At this juncture a criticism is frequently made that with the continued rapid development and improvement of technical process and increased application of power, the productivity of labor will increase to such an extent that we shall again see a surplus of labor. Such argument however overlooks two important economic facts; firstly

we never have experienced the overproduction of goods—we only overreached periodically the purchasing capacity of the people; the need for commodities seem to be very far from saturation as yet and, secondly, when this will happen (as it eventually may), it would mean that the productivity of labor has increased to the point where only a fraction of present working hours will be required to produce more wealth than ever; hence the length of working day may be correspondingly reduced without any diminution of production or casting off the surplus labor.

Qualification of Men

At the time the author presented his paper on Task Setting for Firemen, etc., before The American Society of Mechanical Engineers in 1913, a discussor called attention to an omission of the question of selection of men. The problem of employing fit men is quite distinct from this of fitting employee for their jobs. While it is unquestionably true that the performance of the plant depends on the initial quality of the attendants, it seems to be of greater importance to find the way for overcoming the obstacles presented by difficulties or even at times impossibility of hiring men with all the desired qualifications. As the matter stands in this country, any employment manager could testify that the applicants for job of a fireman are willing to take almost any other job, if it pays better, or is more pleasant. On the other hand, the only three qualifications for fireman's job that are generally recognized—strong physique, previous experience, and state license—are as vague as unessential.

If a concern has a chance to choose let us say a fireman, they should look for somewhat different characteristics. The first test must be concerned with his powers of attention—an untiring ability to notice the minute changes in surrounding conditions; the second with his resistance to influences which tend to distract fixed attention; and third his general good health, perhaps more particularly his ability to resist changes of temperature and strain on the eyes. All other qualifications are chiefly local, depending on dissimilarities of plant equipment and lay-out, as for instance, in a hand-fired boiler-room a short fellow is preferable to a tall one; in a stoker-fired plant muscular strength is non-essential particularly if special men clean the fires and ash-pits. Again, previous experience is very often a decided disadvantage in a plant where no special provisions are made for a thorough training of men on the basis of established facts. The old habits acquired under dissimilar conditions of previous

employment may prove to be wrong for the new job. Locomotive firemen often fail on stationery boilers, and men accustomed to a steady load take a long time to get used to work in a plant where the load frequently fluctuates. But above all the requirements for a license is to be deplored; fixed by law-makers for reasons obscure to themselves, examinations do not put any stress on the most important requirement—the knowledge and experience in economical generation of steam; the regulations as to safety are more properly within the domain of watch engineers, while the familiarity with dimensions, proportions and features of design of boilers could likewise be safely left to draftsmen.

The basic cause of losses due to hiring poor men seems to be in the lack of attraction offered to the better grade of applicants; again, the losses due to a large turn-over of power-plant employees is chiefly due to dissatisfaction with some condition of employment—it may be treatment, hours or wages, but whatever it is, we must realize that frequent changes of positions is as much of a disadvantage to the employee as to the employer.

When, however, the operating practice is standardized and provisions for "filling" vacancies and training of the new employees are properly carried out, both causes of loss are greatly minimized. First, the new man should be put to work under the best conditions that the ingenuity of management and coöperation with employees can devise, which as a rule, is more desirable financially and otherwise than it is in an average old-fashioned plant. Secondly, if the employer does not look for a "ready-made man" but is prepared to start him from the beginning with helpful training, the long period of wastefulness while the new man adapts himself to the new requirements (if indeed he can do so without systematic and persistent instructions, encouragement and help) is not only greatly shortened but when he finally acquires the new habit, he works not "as good as he can" but as good as the management knows how. Whatever forms are used to keep the man's record one consideration is paramount and that is that the *man's record reflects the ability of the management to lead its men.* If men do poor work or are not steady it spells *incapable leadership.*

The plan of thorough instruction and training for firemen, engineers, and other plant employees simplifies the problem of securing the powerhouse help and in fact, solves the problem by developing the skill, intelligence and efficiency of the employee to meet the highest requirements for each position.

Any administration that neglects to provide proper training for

Man RECORD CHART FOR DEPT. DATE Week Ending March 8th, 15th 1919

NAME	NO.	Mon. 3	Tues. 4	Wed. 5	Thurs. 6	Frid. 7	Sat. 8	Mon. 10	Tues. 11	Wed. 12	Thur. 13	Frid. 14	Sat. 15
PALEN													
Griffen	501	64%			52% A	28%				72%		28%	
Palen	503												
Millspaugh	507												
Owens	514												
Rogee	517												
Williams	519												
Martell	527												
Stewart	535												
REYNOLDS													
Marchand	508	46%			24% A	30%			54%		12% A	34%	
Bradford	518												
Rusk	525												
Gerhardt	526												
Forbes	529												
Lewis	530												
Groth	531										LEFT		
Plepzig	532												
Swartz	533										LEFT		
Shorter	534												
Healey	537												

Gantt's Man Record Chart

Width of Daily Space Represents Amount of Work that should have been done in a Day.

Estimated Time needed to do Amount of Work Actually done in a Day.

Time Taken on Jobs for which we have no Estimate or Information

Weekly Total of each Operator.

Full Line for Time for which we have Estimate.

Dotted Line for no Estimate or Information.

Weekly Total for a Group of Machines.

Weekly Total for a Department.

Drawn below the Line Represents Time Allowed on Jobs Spoiled

The Portion of the Daily Space through which no Line is Drawn shows how much the Man has Fallen behind what was Expected of him.

Reasons for Falling behind:

A-Absent, G-Green Operatar, H-Lack of Help, I-Lack of Instructions, M-Lack of, or Trouble with, Materials

R-Repairs needed.

T-Lack of, or Trouble with, Tools.

FIG. 49.—MAN RECORD CHART

Gantt's method of graphically representing man's accomplishments, is to plat for each man on the time scale the percentage of work done to that expected, and explain the shortage by stating the cause, allocating the responsibility.

the employees, clearly fails to fulfill its duty. The means for such a provision, however, are by necessity very different depending on the size of the plant. While in a large central station, the plant office acting as custodian of information has delegated permanent instructors with each shift in boiler, pump, turbine, and high-tension rooms, on the switchboard and with the repair gang, a smaller plant in a mill or isolated building may be satisfactorily served by a single man acting as instructor and supervisor, or even by an outside expert serving in this capacity a number of plants. Between these two extremes a number of variations are possible in every case however, the requirements for peculiar abilities of instructors varying accordingly.

The functions of an instructor do therefore determine his qualifications. He must be at once an expert and a tactful human administrator. Demoralization that may be caused by a lack of either is serious and far-reaching, and it is commonly known, that when perfectly good orders, issued by the management, fail to produce the expected results, the cause can almost invariably be traced to the fact that it was expected that the new order would take place by itself. The old saying that the best way to doom a thing to failure is to give it "a fair trial" is always true whenever a capable man is not made responsible for the result to secure which he is given necessary authority.

Again, a power-plant research man shall first of all be scientifically trained for vigorous, exact and minute observations. He must possess in a very large degree a power of abstraction; he must be able to concentrate his thoughts and attention on one specific subject at a time to the complete exclusion of all else; he must have a broad vision and vivid imagination. He should be physicist, mathematician, economist, and largely a psychologist. To fill such a bill is not an easy job and our colleges are giving little help in this respect, as their programs are calculated to give the students ready made formulas and drill them in administering the textbook data rather than cultivate in the young men the faculty to see things as they are and to do them as they should be.

Charles W. Eliot, president emeritus of Harvard University, justly emphasized the difficulty of securing this high type of men (which fact undoubtedly is explaining the general poor efficiency of our even best power plants) by stating in a lecture delivered in Carnegie Hall, N. Y., this sad truth:

"The war has made plain to multitudes of people what was known before to a few, that human testimony is as a rule untrustworthy,

not because the witnesses intended to deceive but because they were unable to see, to hear, or describe correctly what happened in their presence. This inability to see, hear, touch, and describe accurately is by no means confined to ignorant or uneducated people. Many highly educated American professional men have never received any scientific training, have never used any instrument of precision, possess no manual skill whatever, and cannot draw, sing, or play

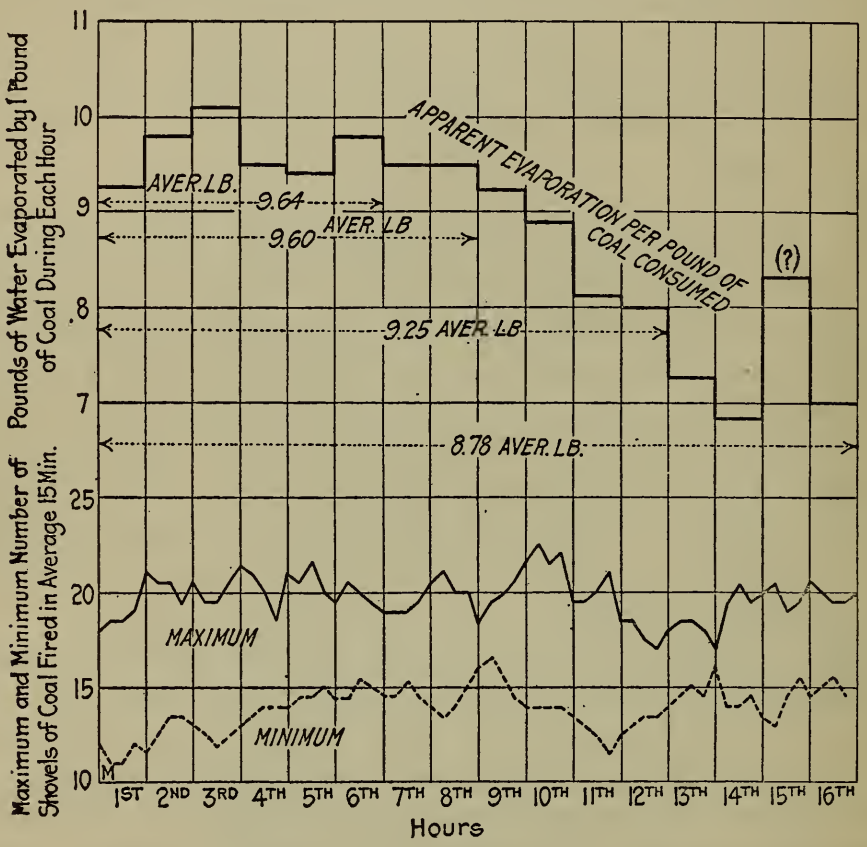

Pounds of Water Evaporated by 1 Pound of Coal During Each Hour
Maximum and Minimum Number of Shovels of Coal Fired in Average 15 Min.
APPARENT EVAPORATION PER POUND OF COAL CONSUMED
AVER. LB.
9.64
AVER. LB.
9.60
9.25 AVER. LB.
8.78 AVER. LB.
(?)
MAXIMUM
MINIMUM
M
1ST 2ND 3RD 4TH 5TH 6TH 7TH 8TH 9TH 10TH 11TH 12TH 13TH 14TH 15TH 16TH
Hours

FIG. 50.—DECREASE OF EFFICIENCY WITH THE LENGTHENING OF THE WORKING DAY

The quality of firemen's work is noticeably dropping when they are kept at work 8, 12 and 16 hours, although the quantity of work does not change appreciably as physical fatigue affects the attentiveness more than it does strength.

upon a musical instrument. Their entire education dwelt in the region of language, literature, philosophy, and history. Their habits of thought permit vagueness, obscurity, and inaccuracy, and their spoken or written statements have these same defects.

"These facts strongly suggest the urgent need of modifying profoundly the programs of American elementary and secondary schools. They must no longer cling almost exclusively to languages and literature and the elements of mathematics. They must give a considerable part of school time to the sciences and arts, and to

the acquisition by every pupil of some skill of eye or hand or both, and at the same time must increase rather than diminish the amount of training they give in memorizing, in discrimination between the true and the false, the good and the false, the good and the bad, in the selection of premises, and in sound reasoning." [68]

The work of men unfit or unprepared for their jobs is not only wasteful, detrimental to the society, and harmful to the employees but at the same time it amounts to no less than a misfortune to the men themselves. By selecting "fit" men, we do not mean of course employment of "ready-made" men but merely men possessing suitable qualifications and at least capable of development, for it is unquestionably a duty of industrial administration to adopt, instruct and train men to perform function for which they are preeminently suited.

Again, asking for references provides a very easy way for one to fall a victim of prejudice and to lose an opportunity to engage a good man who was unfortunate enough to work under incapable direction or under conditions and surroundings handicapping development and demonstration of his capabilities. In the author's own experiences he has seen indifferent watch engineers becoming excellent executives, poor clerks proving expert combustion engineers, wagon drivers turning efficient clerks and men with most atrocious reputation proving the most trustworthy, reliable and loyal managers.

The Working Day

The eight-hour working day seems not only to gain universal approval but international recognition as well. Yet the time, this most important measure of human life, has surprisingly little meaning so far as measuring the productivity is concerned, for the mere lapse of time reflects by no means the use made of it. In other words, the statement that the working day shall be of eight hours duration actually means only that the workers are granted sixteen hours per day for recuperation, propagation, recreation, etc. It is of course true that with a given development of technique of production, accepted standard of workmen's training, customary intensity of work, existing managerial organization, and prevailing understanding as to a reasonable daily output per man, an average may be determined what rate of production corresponds to an eight-hour working day.

Frederick W. Taylor in his paper on Shop Management lays particular stress upon the fact of "soldiering" by the workmen. This work has been followed up by a wealth of investigations (some

of great minuteness, exhaustiveness and accuracy), time studies, motion studies, micromotion studies, etc., which have disclosed the fact that a very large number of variables enter and so radically influence the productivity of an hour's work, and that the measurement of time has gradually become of an auxiliary character, merely in relation to a prescribed amount of work. Serious objections raised by some labor organizations to "speeding up" and prohibition of the use of stop-watch observations of the workmen in governmental establishments furnished additional proof that the length of the working day is only a vague measure of productivity of labor, if indeed it is a measure at all.

The investigations conducted along radically different line of thought disclosed still more startling and important facts. Data collected by Gantt, and those using his method of investigation, demonstrated not only that a large proportion of work done in various industrial establishments is being done without any knowledge as to now long the jobs should take (see Figure 46) but that an enormous amount of time is necessarily lost by workmen on account of an enforced idleness due to various reasons beyond their control. It was thus shown (see Figure 49) that the productivity within the same time could be nearly doubled through better attention to managerial functions, leaving the personal efficiency of the workmen as it is. Or, putting the résumé of this lesson into different wording, the observation over a very large number of great variety of American industrial establishments prove that with proper managerial methods, though with the same equipment and the same efficiency of workmen, the same volume of production may be secured in six hours as now takes ten under faulty management. Lord Leverhulme in his English factories actually has proven this possibility. With gradual improvement of managerial methods and responsibility for the avoidable idleness assumed by the administration of the establishments it was only natural to observe steady shortening of the working day and in nearly all cases where the management insist on longer hours[67] it is due to its incompetency to avoid the loss of time during which the employees are prevented by some form of mismanagement to employ their time productively.

It thus appears that the length of working day depends upon:

1 Efficiency of the management

2 State of productive technique

3 Attitude of workmen.

Each factor in itself is very complex and all of them are in individual cases interlinked. Assuming for instance that the state of productive technique is constant (as in an established industry using a standardized process and existing equipment, etc.), the managerial methods and policy has nevertheless a far greater influence upon the daily productivity than the attitude of working men, for in the last count, their attitude is in itself largely a creation of management. Again, while under the regime of private ownership and wage system either of those factors independently is capable of totally wrecking the enterprise, only the management or rather administration, possesses the necessary means for increasing the productivity of hour's work.

What we termed as the attitude of the workmen is perhaps the most complex thing embodying all the cumulative effects of the entire social-economic structure of society. It is beyond our scope to dwell upon this analysis; in passing, as an illustrative glimpse, let us mention at random a few distinct contributing elements. The treatment accorded the workmen by owners, managers, and foremen is likely to create either an attitude favorable or hostile to the prosperity of the establishment. The training of employees, if conducted with the sole intent to "save a dollar," is met with passive indifferentism, while if carried on with the object of assisting the employee to better himself in his vocation (which will be of help to him anywhere and only incidentally to be of benefit to his employer) it does prove fully successful and goes a long way toward industrial peace. Suffice it to note how apathetic and even antagonistic are the men when taught something they know from their familiarity with the trade will not be applicable in their future places of employment. One more example of broadest nature is rendered by class-consciousness of the workmen in determining their attitude toward the increased productivity of labor. Men well read on the subject of economics do not entertain the same fear before scientific innovations that tends to increase the productivity, for they have learned that the ultimate result of improved methods means growth of the industry and better conditions of employment. It is not so however with uneducated and unsophisticated men: they resent the improvement, lest to-morrow their higher productivity will squeeze out of employment some fellow workman. This attitude however is rapidly waning under the influence of the lessons of the War and more profound thinking done on the subject. In the Resolutions on Reconstruction, adopted by the British Labor Party in June, 1918, the need for increased production is mentioned at the head of the document. It specifies and modifies this aim in these words: ". . .

The conference recognizes that it is vital for any genuine social reconstruction to increase the nation's aggregate useful commodities and services; that this increased productivity is obviously not to be sought in reducing the means of subsistence of the workers whether by hand or by brain, nor yet lengthening their hours of work, for neither 'sweating' nor 'driving' can be made the basis of lasting prosperity . . ."

With these clear-cut explanations *the demand for the increased production means nothing else but a challenge to the industrial managers to attend to their jobs for the benefit of the nation.* About one year before the above statements were proclaimed, Sidney Webb, professor of public administration in the University of London, stated that the function of the manager is "to promote the efficiency of the enterprise; or to put it more shortly, to increase its net productivtiy . . . But the reduction in the cost of production effected by the management must, to be justified, be a genuine decrease of cost, that is to say, a reduction of the human efforts and sacrifices required per unit of output . . ." [68]

Here again we return to the question of working hours. Lord Leverhulme in his recent book, published in this country by Henry Holt & Company, quotes Samuel Gompers as saying: "Bring in all the improved and new tools you can find. We (union labor) will help you to improve them still more, and we will get the utmost product out of them; but what we insist on is the limitation of hours of labor for the individual to eight." Commenting on this statement the author adds: "That is almost word for word what I have said except for the eight instead of six. We want higher wages, shorter hours, a larger production of everything, so that we can get a cheaper cost. Without that cheaper cost we can have no funds to pay higher wages. Higher wages are merely a shadow unless you have lower costs giving increased purchasing power with the higher wages; and I believe with that and shorter hours we can realize all that we are striving for." For many years past this viewpoint was developed and advanced by the author and it has been referred to before earlier in this work. It is interesting however, to record Leverhulme's exposition as an indication that the economic status of England under the post-war conditions made that country realize the fundamental truth of *economics viewed from the standpoint of service.* Similarly, Walther Ratenau, Technical Director of Allgemeine Electricitäts Gesellschaft in "The New Political Economy," admits that *"the progress of the country's development and success in international relation no longer depends on profits and dividends,*

but on wise economy of human energies." We must not forget, if as a nation we desire to develop, that every ton of coal wasted means not only so many needless hours of work, not only so much wanton destruction of our natural resources but that it will inevitably result in a shortage and dearth of all essential commodities.

The six-hour workday advocated by Lord Leverhulme in his opinion: "can be applied forthwith with enormous gains in cost of production, provided the supply of raw material and of labor is available and the demand for products exists." "There could be no question of desirability and advantages of shorter hours in any industry where the overhead charges are equal or larger than the cost of wages." In the chapter on equipment the reference was made to the large expense incurred of overhead in an idle plant. While in the case of a central power station the applicability of this criterion alone may appear obscure, suffice it to say that a public utility or factory plant serves industry to a large extent. With shorter hours, shift work will become indispensable and consequently the idle time of expensive equipment provided for part-time only will be greatly reduced.

Again, in the power industry, it may be shown clearer than in some others that shorter hours have other strong arguments for its adoption. A typical comment is to be found in a letter which the author received from an American engineer of note, a manager of an industrial plant, written after the author's suggestion to substitute for the firemen's two twelve-hour shifts three eight-hour shifts.

"We did carry out your recommendation on the reduction of hours of work for firemen and certainly have found this highly satisfactory.

"We believe that the eight-hour shift pays us, for the following reasons:

1 We have been able to get and hold good firemen

2 While we have not the accurate data to support opinion, we feel satisfied that there is a saving in coal

3 Our variations in steam pressure have been practically eliminated.

Fatigue

Closely bearing on the subject of length of working day and intimately relating to the economy in power production is the question of fatigue. It is not within our province to discuss here the effects

of fatigue toxines on the nervous system and vitality of workers for many excellent researches have recently been made on the subject and to these we shall refer the readers. The point of immediate importance is the ill-effects of fatigue on industry (and hence society), and some means of its elimination. It has been pointed out by those studying the subject that *the greatest proportion of occupational fatigue is of nervous origin.* Charles S. Myers, Director of Cambridge Psychological Laboratory, has explained that "the central nervous sysetm (the brain and the spinal cord) acted as a protection against muscular fatigue, and it was only in the extremely strenuous work of comparatively few occupations that there was a serious degree of muscular fatigue." Indeed, when a person was actually fatigued, he might temporarily do far better muscular work than when he was not, for *certain status of fatigue produce a feeling of ability to work, though the work may fall very short in quality if not in quantity.* This fact is of great importance to power-plant work, where the quality of work is of paramount importance while quantity economically is of very slight value. In the case of firemen attending hand-fired furnaces numerous tests are on record plainly indicating that as fatigue grows, the ability to shovel coal into the fire door does not appreciably diminish within reasonable limits, while the quality of combustion is getting steadily poorer as indicated by number of pounds of steam produced per pound of coal.

A typical summary of twenty-six tests made by the author, of which eight were of sixteen hours duration, are graphically represented in Figure 50. It appears from these tests that if the quality of eight-hour work taken as 100 per cent, the reduction of working day to six hours increases the efficiency slightly less than one-half per cent, while the increase of the working period to twelve hours a day reduces the quality of work about 4 per cent and further extention of work to sixteen hours drops the efficiency 8.5 per cent. Great accuracy cannot be expected from these observations as they were made occasionally and with men habitually working eight hours a day. The slight improvement shown on the six-hour shifts may be explained by the fact that their former habitual eight-hours work did not give them sufficient previous rest to accumulate a reserve of nervous, mental and physical vigor; again, keeping men longer than usual, (either purposely as in the twelve-hour instances or on account of sudden illness of relief firemen as in cases of sixteen-hour work), may tax their ability to concentrate and capacity for work but not nearly in the same degree as it would be if the same men were regularly working twelve or sixteen hours per day. In fact the higher

quality of the eight-hour men is clearly seen when men who for years worked eleven and thirteen hours per day were put on eight-hour shifts; in such instances their efficiency increases at least 4.5 per cent and in several observed instances 5.6 and 6.2 per cent. These figures again are not entirely indicative of the beneficial effect of shorter hours for the ill-effect of previously accumulated fatigue, through years of long-hour work, could not be expected to disappear in a few months. In all cases of our recorded observations men themselves were unaware of the fact that data of their work will be used for this purpose.

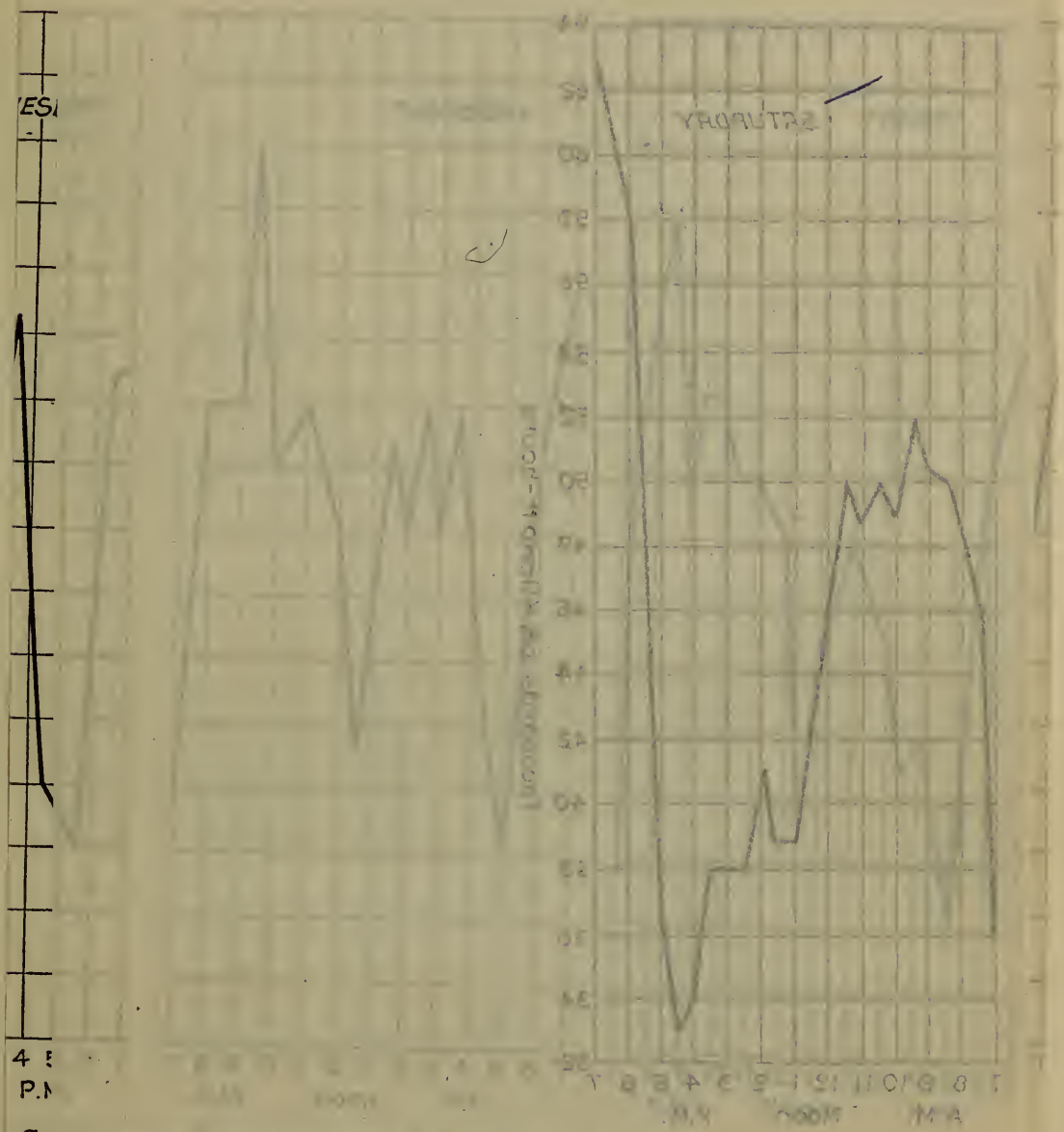
In cases of mechanically-stoked boilers the physical fatigue plays a subordinate role whereas factors of nervous and mental origin obviously predominate. It is significant to note that the monotony of work in fire rooms equipped with stokers whose motions are hardly perceptible, where the silence or monotonous humming is seldom broken and illumination usually best adapted for slumbering meditations, has a most ruinous effect on the economy. The feeling of weariness and fatigue arising from this deadening monotony makes long hours for firemen not only nerve-wrecking but highly extravagant from the viewpoint of economy. While periodic rest and recreation may prevent large turn-over of firemen and a don't-care spirit, and such means for dispelling the monotony are extremely valuable both from the standpoint of welfare and of economy. With almost no exception, the rule that proportionally larger savings of fuel may be made in the mechanically-stoked boiler rooms than in the hand-fired ones, is to be attributed principally to this fatigue-producing monotony. Installation of instruments, requests for log-keeping and brighter lighting alone have shown in the writer's experience a marked increase in economy, sometimes reaching 20 per cent improvement in efficiency. Yet such measures alone cannot be depended upon to produce lasting effect as they themselves, in course of time, will lose their stimulating value of novelty and become familiar, monotonous adjuncts of the "old dirty hole." Intellectual awakening, training, competition, sporting spirit, bonuses and other forms of incentives are therefore producing as a rule favorable results, even when clumsy and unfit. Furthermore if inaugurated with proper thoughtfulness, upon a thorough analysis of all circumstances and in accordance with a far-sighted policy, these and similar measures are completely regenerating the spirit.

Many methods and various kinds of apparatus have been proposed for studying and measuring fatigue; among them being ergographs, Krapelin's instruments, Gilbreth's methods, and Lovatt and Martin's

dynamometers. Their value is usually greatly reduced by the fact that while the subject is under observation he is stimulated by a complete change of work, surrounding and line of thought. The best means so far known of estimating occupational fatigue is by a study of hourly output during the course of a day; another way is to observe the power used from hour to hour. Diagrams of power-output from a central station, having no traction load, are in this respect interesting if allowance is made for the amount of electricity used for lighting. Figure 51, showing the fluctuations in power demand for driving various machinery in an industrial community, may be compared to advantage with charts obtained from observation on a number of accidents arising through carelessness caused by fatigue (see Figure 52), and relation between hourly outputs and power used (see Figure 53).[69] The valuable part of these comparisons even of much dissimilar cases, such as the purely manual work of dock laborers, highly mechanistic work in machine shops and monotonous work of spinning mill and a group of industries such as colliery, foundry, tailor establishments, quarry, china-ware works, repair shop, etc., both in the United States and in Europe, seem to establish beyond much doubt the similarity in waves of fatigue and efficiency.

But generalization from a typical case or from individual test, however interesting, lack nevertheless the indications as to how the fatigue accumulates from day to day during the week. Referring again to Figure 51 the Monday chart undoubtedly shows the "feeling of fatigue" after Sunday's rest; again while the power demand is fairly steady and the peaks uniformly high in both morning and afternoon they do not reach the same height as on Tuesday when the feeling of realization of fatigue is somewhat worn off; the periods of high output during spells are noteworthy by their durations. On Wednesday morning the fatigue is not felt as yet, but in the afternoon it begins to manifest itself by the steady declining use of power. Thursday is a day when the industrial community becomes really tired; after a short effort in the early morning the work drags 14 or 15 per cent less actively than on Tuesday. On Friday a supreme effort is made at the start of the day, but its collapse follows at once and the output rapidly falls in an avalanche fashion to the lowest point on the record. Saturday morning finds men without any ambition left—no peaks indicate the absence of the morning spell—although the men probably being spurred by anticipation of the holiday and some likely rushing to finish their week's tasks.

The accumulative fatigue, so plainly evident from these graphs



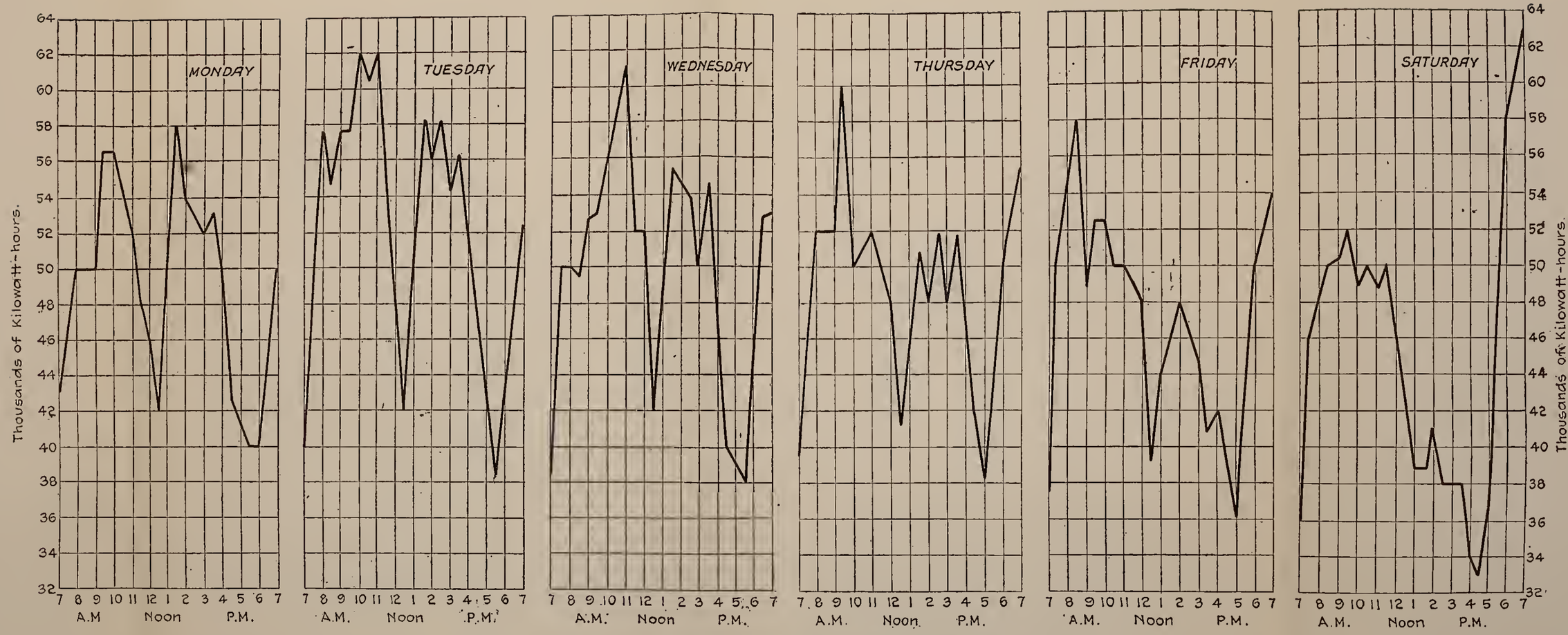
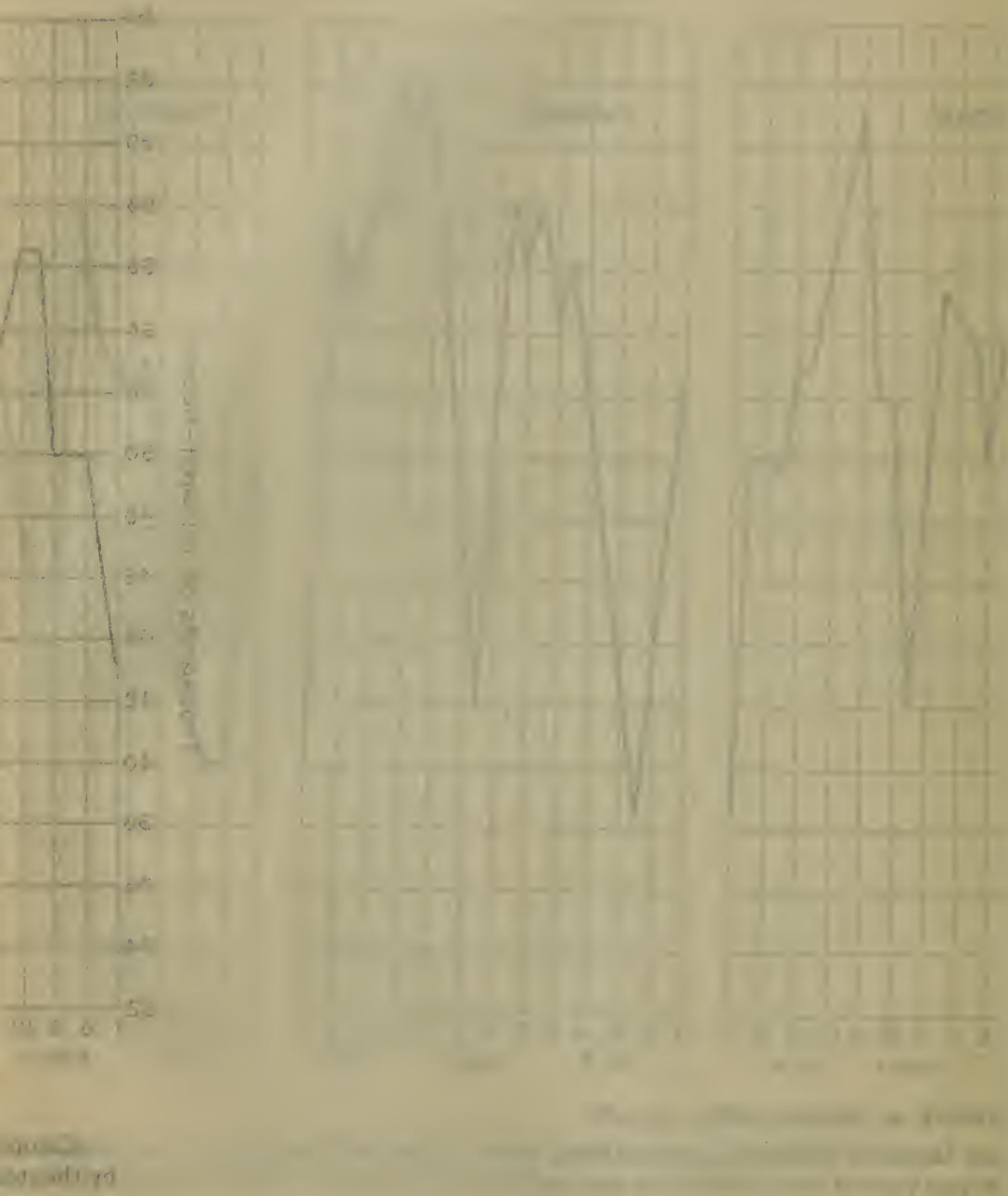


FIG. 51.—FLUCTUATION OF POWER CONSUMPTION INDICATING THE INFLUENCE OF FATIGUE

Composite diagram of electrical load of a public utility plant carrying diversified industrial load. Monday's incitement is apparent. Gradual accumulation of fatigue in the industrial community is plainly indicated by the steady decline of power used. A week of four working days and fifth day as a holiday may increase total annual production.



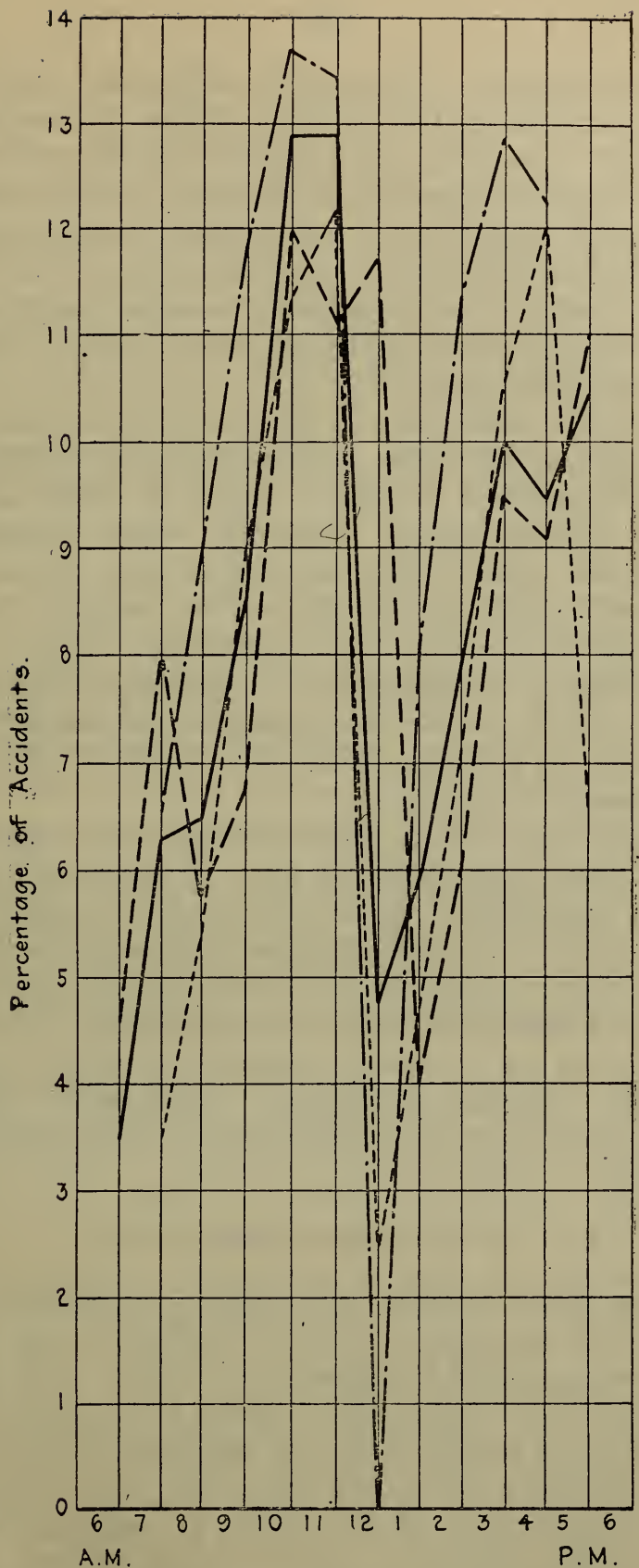


FIG. 52.—NUMBER OF ACCIDENTS IN RELATION TO FATIGUE

Maximum number of accidents occur between 11 a. m. and 12 noon and between 3 and 4 p.m. This coincides with the beginning of decline in power consumption; as result of fatigue—less work is done and less care is taken.

is of utmost importance; it seems to indicate not only that the seven-day week, while suitable for biblical times and occupations of that degree of civilization, is too long for our days of strenuous efforts.[70] It suggests, however, the desirability of securing similar data for the fifty-two weeks of the year showing the accumulation of fatigue throughout that period. Unfortunately this kind of data is exceedingly difficult to secure because of seasonal fluctuation of the amount of work, number of employees, climatic changes, and numerous other interfering factors.

However, these wavy lines of fatigue and spells have a great deal more than academic value. By a careful study of them the possibility of combating the ill-effect of fatigue on health, safety, and productivity may be devised. In certain manual operations performed in power plants such as wheeling of coal, the intermittent work and rest periods were arranged after exhaustive tests with the result that the men who were fatigued and ready to "fire the job" not wanting to "kill themselves" by wheeling in 45,000 pounds of coal in twelve hours were made contented, and though the job is a "cinch" when, by following instruction, (Figure 71) they wheeled in 60,000 pounds in eight hours.

The reduction and general gradual elimination of fatigue through adequate rest and proper recreation, better adapted tools (see Figure 54A) and surrounding of work, substitution of interest in work for monotony, etc., is the task of utmost importance from the viewpoint of national economy as it at once not only conserves the health of the nation and increases the productivity and well-being of the community but it materially conserves our fuel resources for the posterity. *The task of engineers viewed in this light is to provide opportunities for leisure rather than to invent new yokes and tread wheels.*

Universal Labor

In the past the use of terms "manual labor" as opposed to "mental labor" has been warranted, as lines of distinction were decidedly drawn by the nature and conditions of the work. With the enormous advance of technique and the advent of automatic machines this purely external distinction has been obliterated however in many instances. A fireman graduated from Cornell University and from Stevens Institute, with an M. E. and Ph. D. analyzing coal, ashes and gases, making deductions from instrument readings, adjusting conditions controlling the chemical processes of combustion and physical phenomena of steam generation, getting wages twice ex-

ceeding these of an office worker, tangles inseparably all our old conceptions of the subject. A different classification seem to be more in order—this between *coöperative* labor and *universal* labor. Under the first class there falls all labor performed in coöperation with living working individuals, and aimed toward the production of any material results, whether by use of brains, muscles or both, while the *universal* labor is conditioned not merely by coöperation with living fellow-beings but by ideas and work of those who have gone before and aimed not merely toward the production of a particular material thing but toward the discovery of unknown facts and development of new methods. The greatest benefit accruing from this scientific labor for humanity is usually exploited in the most shameless manner. This class of men, working mostly individually, are not organized to collectively resist the unfavorable terms of individual bargains. The beggarly compensation they receive is in no wise commensurate with the lavish benefits derived by the enterpreneurs acquiring their discoveries or inventions of new methods and means. Professors, working for salaries lower than wages of coal passers or ditch-diggers, inventors starving to death while their patents heaped fortunes to others, and engineers getting one-fourth of one per cent of the value of their services are examples only too well known. The greatest danger to our civilization and future progress is indeed in this systematic discouragement of creative, scientific work and art; driving this class of men through privations, discomfort and even starvation out of existence is bound to bring our development to a standstill and degrade our civilization.[71]

A. The foundation of our economic, industrial and business system lays in the service rendered by all the preceding generations of humanity. A sewing machine is capable of increasing the productivity of its operator not only by the amount of labor worked into it by the mechanic who made it, but the integrated services of all the scientists, philosophers, artisans, etc., and of all those who directly served to make their life and work possible back from the ages of primitive men. If this were not so, the productivity added by the use of a machine would be equal only to the productive efforts expended in its construction. The laws of Mayer and Lavoisier, that energy and matter cannot be created or annihilated, would receive its death blow by the first yard of stitches made on the machine in excess of the energy expended by all the living coöperating workers. The law of nature remains in fact inviolate, but the "time saving" capacity of machines is the mani-

festation of the service of dead men, who passed to us their ideas and knowledge. This ever-increasing accumulation of our material, intellectual and spiritual wealth is, therefore, not so much the fruit of our toil as that of preceding humanity.

B. The steam engine, for instance, is not the creation of Watt nor is the power loom the invention of Hargrave alone. Philosophers and thinkers, who discovered the laws and forces of nature, the chemists and metallurgists, the technologists and engineers, scientists, doctors and school teachers, all have contributed to develop a state of science whereby our knowledge today is so immense that we can perform work and accomplish things short of marvelous. No man can today further develop the technique of production, unless he is helped by this vast amount of knowledge which was accumulated in all countries and in all ages. We cannot even begin to count the number of these brain workers, who have died long ago, no matter how small was their individual contributions, the total of which is so great that it easily explains why we have today such labor saving machinery and apparatus, which apparently could produce more than all of us living people could possibly produce alone, within the period of our short lives.

C. In the case of coal for instance, it takes on the average four men hours to get out and deliver one ton of coal. But this one ton of coal, if burned under the boiler can develop at 10 per cent efficiency, something like one thousand horse-power hours. This energy of four miners, one fireman and one engineer and a few people to help them in this work, which in total would not be equal to even five horse-power hours, is capable of saving over 200 times as much labor when this mechanical power takes the place of human work. In this case, we get the benefit not only of inventions and ideas of the past generations but we also draw fully from the stores of nature.

The production of power has always been in the hands of engineers who are preëminently masters of materials and students of the laws of nature. The very foundation of engineering activity is the knowledge of facts, measurements, the relation between causes and effects, and the interplay of phenomena, the engineers are called to master, is reckoned in terms of mathematical equations and formulas but—what sarcasm! So long as the engineer remained a satrap and an obedient servant of his master, his knowledge, initiative and ideas counted for naught—he was paid to carry out the will of his employer! The law-maker and the money-lender were taught by sad experience that improper design or faulty calculation spells

damage and money loss, but once physical safety of investment is assured, the operating perfection mattered little, so long as the losses in the power *production* could be covered up by other opportunities that *business* presents. Moreover, bromided accounting showing a net revenue can cause no concern regarding the extent of power losses as it has no means to disclose and measure them. Hence the

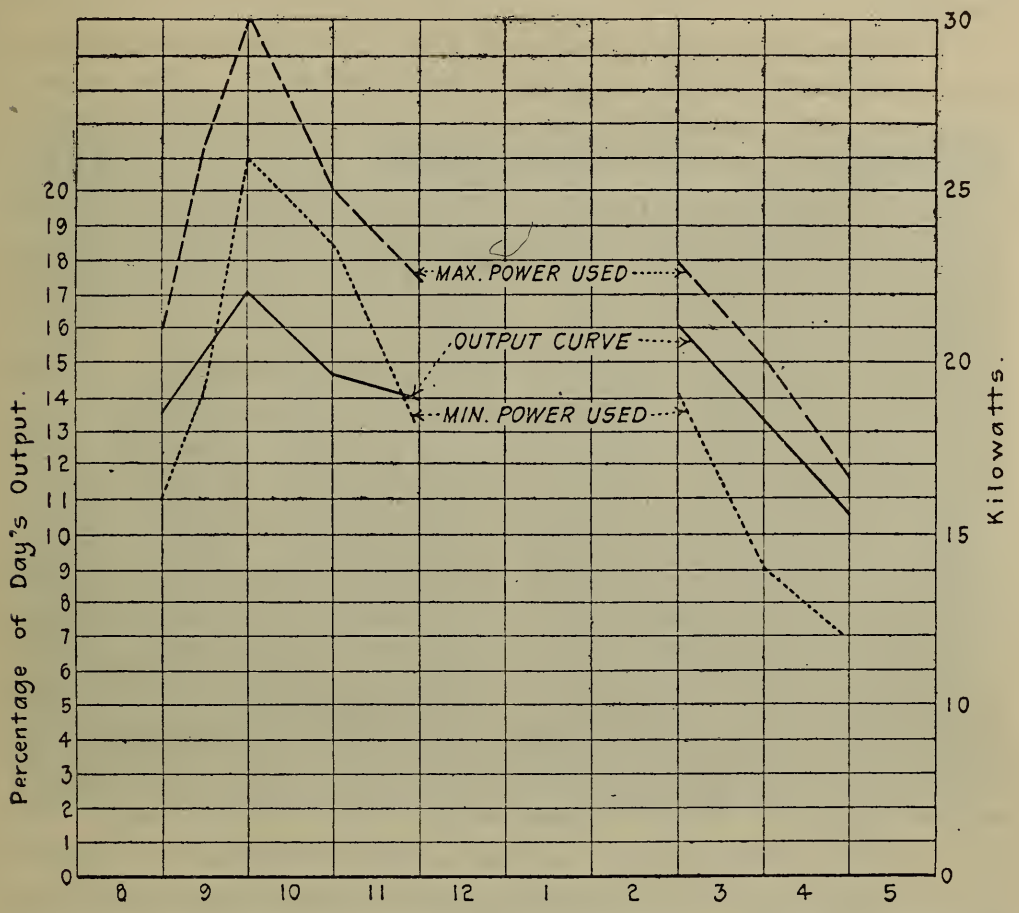

MAX. POWER USED
OUTPUT CURVE
MIN. POWER USED
Percentage of Day's Output.
Kilowatts.
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
0 10 15 20 25 30
8 9 10 11 12 1 2 3 4 5

FIG. 53.—HOURLY FACTORY OUTPUTS AND POWER CONSUMPTION AS AN INDEX

This chart based on observations of the Director of Cambridge Psychological Laboratory, Mr. Ch. S. Myers, establishes the relation between output and power consumption. Compare with Fig. 51 of decrease of power consumption during the week.

boilers were equipped with safety valves and water gages; generators with voltmeters and circuit breakers, feeders with time relays, while the instruments enabling the operating force to adjust the conditions for the best economy and to measure the efficiency attained in each stage of the transformation of energy, from coal pile to its ultimate use, were generally ill favored by investors.

While the economic structure of our social and industrial relations started to shake to the root under the effects of the World

War, the problem appeared before the investing class in a new aspect. It is no longer the question of losing little in one direction and gaining more somewhere else. The wanton destruction of our fuel resources in mismanaged power houses appears from time to time as a ghastly spectre of fuel famine[72]; the power shortage threatens to stop the dividend grinding machinery and the day of reckoning has come.

The relief was sought however in the old, time-honored method—more machinery, better equipment, special privileges. The government was asked to furnish the money to modernize "public utilities," the government was forced to issue priority orders, the public had to pay excessive cost of new construction carried on under abnormal conditions. The volume of electrical business multiplied, even smaller rate of profit would yield under such conditions a larger bulk of dividend but in spite of it all petitions were filed to raise rates of electricity, to increase fares, to discontinue transfers, to permit skip-stops, etc., all of which has been done contrary to the advices of engineers and against the benefit to the public. The poorly paid, and little respected body of engineers had no voice in the matter of national economics and production. Lawyers, not engineers, were asked what to do and how to do it and after due debates by those who know nothing of the subjects the financiers and manufacturers were allowed to do it. And they did. . . .

We do not need to be surprised at the frequent public statements that the "dollar-a-year" patriots were "over-paid" for their services for indeed their intentions were far better than their education and accomplishments. Even the engineering societies—these bodies representing the universal labor—showed a remarkable degree of modesty if not a self-denial in recommending for engineering leadership those who could provide employment rather than knowledge. Seemingly the principal reason for this subordinate role that the universal labor is permitted to play in the industrial and economic development of the country is our proverbial richness in natural resources. When the shortage of fuel began to be felt, the attention was turned by the force of habit to those who had and to those who could protect their title, that is to financiers and their legal advisers. To be sure, they had to ask engineers' counsel but whether they were to follow the advice given or not, was left to the arbitrary opinion of the former.

The progress in the utilization of fuel and power, made possible through the efforts of the universal labor, may be judged from the coal consumption per horsepower hour. While in the early forties

FIG. 54.—FATIGUE-PRODUCING AND ENERGY-SAVING SHOVELS

No man with short-handle shovel with too small a scoop could live up to instruction card for passing coal (Fig. 71). Unless he is using proper kind of shovel, saving thousands of foot-pounds of work, fatiguing unnecessarily the muscles of the back, the fatigue will injure the man and limit the output.

of last century the cotton districts of England were generally consuming from ten to twelve pounds of coal per horse-power hour, to-day only one-fifth the coal is needed to produce the same work. An extremely interesting review of the progress in power utilization may be found in a report issued October 1852 by L. Thorner, in which he quotes from a letter of the famous engineer James Nasmyth of Patricroft, the inventor of the steam hammer.[73]

The effect of improvements in power generation, as well as in transmission and mode of running the working machinery, may be found on page 58 of the Rep. Fact. for October, 1852. According to Redgrave the reduction in cost of power generation and consequent modification of factory processes brought in a typical instance the following changes in earning capacity of the workmen and in number of children employed: "In October, 1840, his firm employed 600 laborers, of whom 200 were less than 13 years old. In October 1852 they employed only 350 laborers, of whom only 60 were less than 13 years old. The same number of machines, with very few exceptions, were in operation, and the same amounts were paid in wages, in both years . . ." In other words the earning increased over 70 per cent and child-labor decreased to almost one-quarter of its number. Another firm (see Factory Report 1863, page 110), using larger engines "can drive the same number of spindles with one single driving shaft, and thus saves from 60 to 80 per cent for gearing as compared to other firms. This, furthermore, results in a great saving of oil, grease, etc. In short, with perfected installation in his factory he had saved at least 10 per cent in labor not to mention great economies in power, coal, oil, grease, transmission belts, and shafts."

Within the last twenty years while the progress in devising more efficient power equipment shows comparatively small improvement—a new avenue has been opened for securing large economies—namely by devising methods whereby the daily average operating efficiency is increased so materially that wherever these methods were consistently applied a saving from 20 to 50 per cent were secured. Though this intensive production was only made possible through the work of engineers and enormous wealth was thus accumulated, they themselves, these trained engineers, inventors, scientists and organizers, are not only worse off to-day than they were years ago but even relatively worse than the men who do manual work.

The application of scientific discoveries and methods to industries, and the introduction of labor-saving machinery lavishly contributed to the intensification of production and increased productivity of

labor. Yet, as it has been with the introduction of power looms, steam engines, railways, linotypes, etc., coöperative labor itself did not take kindly the work of the individual labor. The viewpoint of the working class was plainly stated some two scores of years ago in these words of A. Bebel:

"Everyone in practical life knows with what suspicion the workingman to-day regards every improvement, and every invention introduced into shop. And he is right. He rarely derives any advantage therefrom; it all accrues to the employer. The workman is assailed with the fear lest the new machines, the new improvement, cast him off to-morrow as superfluous. Instead of gladsome applause for an invention that does honor to man and is fraught with the benefit for the race, he only has a malediction on his lips."

The fallacy of such an attitude would be obvious if competition is replaced by coöperation since such increased productivity would then make possible the satisfaction of higher wants. Says the same writer: "Especially will the productivity of labor rise through the discontinuation of hundreds of thousands of small plants conducted with imperfect equipment. But the large establishments could, with hardly any exception, be conducted more rationally than now so that, aided by the most highly perfected technical process, an infinitely larger demand could be supplied. The share of each raises with the productivity of labor and increased productivity again makes possible the reduction of hours of work and acquisition of skill in many directions."

This increased efficiency must however be properly directed before it becomes a real boon to society, as all these wonderful creations of engineers and scientists might easily become the accursed means of destruction and oppression of one part of the society by another.[74] And here again, there opens a new and fertile field for the application of universal labor.

So long as scientific methods of intensifying productivity were monopolized for private gains and not for public weal, the periods between industrial depressions due to overproduction shortened, the army of unemployed increased, but the purchasing capacity of the people, overtaxed by the cheapening of production in individual plants, did not affect the market prices at large. On the other hand the results of these economic conditions lowered the physical standards of the workmen, and prostitution and birth-control gained headway.[75]

Under such conditions, when 5 per cent of the population have almost the entire national wealth, leaving but little to the other 95

per cent, the talk of industrial democracy is but, "sounding brass and tinkling cymbals." The United States census statistics pictorially showing in Figure 5 that things have not gone better since this was written may also be gathered from such reports as that of the Director of the Bureau of Child Hygiene, Department of Health, New York, according to which in 1916, 100,000 or 10 per cent, of the school children were underfed, while in 1918, 21 per cent are undernourished and 61 per cent are on the border line. Again, when our Federal Trade Commission admits that some 78 per cent of our business corporations are managed so as not to get (or show) any profit, it means that they can not properly take care of their employee, it means that lowered productivity of labor is as inevitable as the waste of fuel and inefficiency when the plant is run with poor equipment and improper methods. Such are some of the problems for solution by the universal labor or engineers par excellence.

The Position of An Engineer

The task of an engineer has often been defined as that of securing a maximum product for a dollar's worth of expense. We feel that in order to make this definition free from misinterpretation we must put some capitalization on each man capable to work and charge against the national debit every hour lost through mismanagement, lack of work, lack of skill, sickness, discontent, poor nourishment, poor transportation, and particularly through misapplied effort or labor directed to no useful purpose. And only from this broader, national standpoint, we may hope to realize the true meaning and enormous value of the so-called "industrial paradox" *"that high-priced labor may produce cheap, and low-priced labor may produce dear commodities."*

Gantt and other industrial organizers have since discredited the fallacy that it is necessary to have low wages in order to have low costs, which is detrimental to all concerned.[78] On the other hand the increased productivity of labor under the condition where the production is carried not for the benefit of the entire community or the country but merely for the private gain of an isolated group, the laborer feels that he has nothing to gain. Furthermore, *the old school of management seeing little beyond the trial sheet of accounting balance and knowing no royal road to eliminate the mismanagement tried to recover the losses by increasing exploitation of labor.*[77] The high ideals and honest intentions of Taylor's scientific principles

were only too often misused and abused to the decided disadvantage of labor and doubtful gains to manufacturers themselves.

While these lines are being written, President Wilson's mediation commission published its finding: "The conclusion cannot be escaped (sic!) that the available man power of the nation . . . is not employed to its full capacity *nor wisely directed.*" "Broadly speaking, American industry *lacks a healthy basis of relationship between management and men.* At the bottom this is due to the insistence by employers upon individual dealings with their men."

Whatever might be the ultimate agreement on the controversy of dealing with individual employees of bargaining collectively with labor unions, the same fundamental antagonism of interests will remain as long as employers conduct their business for profit and employees do not participate in the control of production.

To sum up, the immediate problem before the industry is to ameliorate the antagonism of interests between employers and employees. This can be accomplished not through bargains, debating societies and endless "boards," but by a thorough inquiry into the basic facts underlying the economic and human relations. The accurate knowledge of causes and results gives the powerful and indisputable weapon to smash many fallacies and traditions that greatly harm both sides. Yet they involve no other "raison d'etre" than the misconception that what was true yesterday remains so to-day.

Chapter VII

MASTERING LABOR PROBLEMS

THE most efficient machinery is of no avail unless properly operated. In the final count it is neither perfection of equipment, excellence of supplies nor the best of advice that produces the best results but the will of the men that control and operate the plant. Steam consumption of the most efficient turbine may be lower than that of a less efficient one if it is improperly loaded or run at low vacuum, low pressure, with saturated steam and these factors of course depend upon the operators. The most suitable coal in the best furnace and under perfect boiler may show a lower efficiency than poor coal and a poor boiler, if the draft is poorly adjusted, the firing irregular, heating surfaces dirty, etc., and all this again depends upon the operator.[78]

The best instructions may be available and all the facilities at hand to secure highly efficient results, but if the employees do not care to live up to them, the efficiency will remain low. In other words, *there is little use in having a good plant and knowing how to operate it unless the operators are willing to do so.*

Any act of will can be analyzed according to three distinct processes—*perception, choice* and *action.* One can not act unless the choice is made as to how to act (Buridan's ass) and this decision can not be reached unless some stimuli are stronger than others. The influence of heredity, training and environment affect the perception, selection, and action or in other words our will. Therefore, our aims and the manner in which we are pursuing them is in the last analysis determined by the effect that the surrounding conditions have on the individual, and modified by one's hereditary inclinations.

If we admit with Laplace and Spencer the principle of sufficient reason in its limited sense, the logical conclusion would be the denial of freedom of will as every cause resolves itself into a definite single effect. The fallacy of such reasoning was first exposed by Professor A. Petrunkevitch who proved that every cause is potentially capable of producing several effects. What actually takes place, may only vary within definite limits, that is, within specific ampli-

tude of the case. In mathematics for instance we find many equations which have several solutions and that the same effect may be produced by different causes. For instance ellipse, parabola and hyperbola may be derived from:

$$r = \frac{e\,p}{1 - e\cos\triangle}$$

where r and $\triangle$ are polar coördinates; similarly:

$$4 = 2+2 = 2^2 = \sqrt{16} = 5-1 = 3+1, \text{ etc.}$$

and vice versa, the same process may produce different results as $\sqrt{4} = \pm 2$ or several values of unknown may satisfy certain equations. Therefore while it is indisputably true that every effect necessarily has a cause we must admit that, in the case of human will, perceptions will originate feelings and desires, though of different intensity, according to the individual, and the choice between them will be caused by conscious decision preceded by reasoning which again is conditioned by heredity, educational, and social factors. For instance, the case of offering a bonus to the workmen who learn the best way to perform certain work or who live up to instructions describing how to regulate certain process, it is not a foregone conclusion that the bonus will necessarily stimulate all men to the expected action.

In this case we must first consider whether the reward is attractive enough to create the desire: a concern offering 40 cents to firemen for learning how to save $15.00 worth of coal failed to get any response from men whereas men in another plant were eager to learn how to save $8.00 worth of coal being offered 85 cents as bonus for following the instructions. It may be noted that in the first plant the bonus was only 10 per cent while in the second plant over 30 per cent of their wages for the habitual wasteful work.

The second consideration, namely that of choice, sometimes presents to the men a problem as to whether it is worth their while to strive for even an unusually attractive reward and especially so if there is any doubt in their mind as to honest intentions of the employer. It may not appear to the advantage of the men to earn a bonus if they are reasonably sure that after a short time the bonus may be discontinued and disciplinary measures substituted to enforce the higher grade of work which was demonstrated as possible under bonus incentive. Likewise in cases where the work requires physical exertion, a task set by an incompetent or unscrupulous man may be so hard as to endanger the workman's health. The choice in such

a case will be negative as the dictates of reason will suppress the desire for extra compensation in favor of more remote benefit of preserved physical welfare.

This process of choice of accepting or refusing the bonus offered, as caused by reasoning and natural inclinations of an individual, creates endless varieties in the readiness with which the men transmit their decisions into actions and the promptness or slowness, as well as persistence or indifferentism, with which different men learn and continue to perform their task.

Furthermore in considering the case of a plant where the method of operation is undergoing a change, and the employees are given an opportunity to learn an easier and better way, one should not forget that the acquirement of a new habit is a most difficult psychological process and the inducement must be necessarily not only strong enough to influence the decision in favor of the new order but also to overcome the inertia of old habits. This training and fixing a new habit must continue a sufficiently long time to replace the old habit and, what is not less important, it should create a new mode of thinking in substantially different terms. Like men trying to abstain from smoking or drinking, the men under a new mode of management are, in the beginning, working under a great nervous strain and the more gradual is the process, the more sympathetic and helpful is the attitude of instructors and other members of staff, the easier is the process of acquiring the new habit and the more lasting and successful are the results. What is true in this case regarding the manual workers is even more true when applied to office force and management itself for it involves more profound changes in their habtiual work and ways of thinking and reasoning.

The following extract of two letters from the author's file indicates the change in the psychology of those whom the writer had the pleasure to help in such transition period: "I wish you could continue these tests farther," writes the station superintendent of a public utility plant, "for the reason that instruction to firemen during these tests has certainly proven to them that their way of firing is nothing better than ridiculous.

"You have broken some of their bad habits . . . You have shown them some things that they thought were impossible, etc." (Figure 55 is a picture presented to the writer by the above referred crew at the time of parting.)

Now, such an admission on the part of a leader requires a change in mentality short of being revolutionary. It is human to resent, and the way to accomplish the change is not by criticism but by

demonstration and conviction. This point is evidenced by a letter written and signed by the employees of another concern at the close of the author's engagement:

"While here, you have not only placed the plant upon a high plane of efficiency, but also by your kind and helpful way and your diplomacy have succeeded in dispelling every vestige of the hostility to your methods that some of us entertained.

"We feel that it must be a great satisfaction to you that you have accomplished so much, and at the same time gained the coöperation and friendship of the rank and file of the organization. It is significant that the workmen have been changed from doubters into enthusiastic bonus men." Be it said incidentally, that this plant was strongly unionized and our work met with the approval of the organization.

The three major influences under which the man's individuality is shaped—are these of (1) inherited ability and peculiarities, (2) the effect that training and education has on their shaping and development and (3) the environment which not only moulds the man but either gives or denies the opportunity for application of his peculiar capabilities. The first category is beyond the direct reach as far as industrial administration is concerned; the second, that is educational equipment of members of an industrial community was in the past grossly neglected, the prevalent fallacy being that workingman's child needs but little schooling and only the most elementary education. Meagerly paid, unqualified teachers in the public schools; scholastic, abstract programs that train memory for words and crystallyzed precepts instead of drilling the reasoning power for application to actual life and formal discipline in the class room in place of the moral discipline of joyous self-expression in coöperation, such is the mould applied to the new generation called to create life and pursue happiness. Obviously, what has been attained proved to be a failure and eleventh hour measures, such as evening classes, industrial and vocational schools, factory training courses, etc., are but clumsy patches on misfit and worn-out garments. Men whose brains are not trained for quick, precise reasoning cannot perform of their own accord rapid and accurate operations; they are necessarily clumsy, and slow, and waste their energy in useless and difficult manipulations.[79]

Men subject in childhood to formal, unreasoning, military discipline necessarily lose part of their inborn initiative. A restriction of natural impulses imposed from outside creates, by the law of equality of reaction to action, a spirit of antagonism to any arbitrary

FIG. 55.—GROUP OF BONUS WOKERS IN A CENTRAL STATION

The writer received this photograph as a parting gift from the employees of the Penn. Central Light and Power Co. as a token of appreciation of the human side of the work done in connection with reorganization of managerial methods.

order. With the faculty of analytical reasoning undeveloped, the protests against oppressive regime frequently assumes the forms of destructive excesses.

But whatever little good the public schools might have done, is markedly diminished in the case of the poorest children. Parents, who because of low wages or low intelligence or both, fail to provide plentiful and wholesome nourishment for their children retard not only their school progress but, what is more important, ruin their character and temperament.[80]

Whatever part the engineer and industrial leader may play in the reorganization of education and the training of the community, his word and his experience must carry more weight than that of the lawyer, preacher or candlestick maker for it is an engineer who is delegated to organize and direct the productive activities of modern society. The burden and the duty of drafting a specification as to what is essential and what is harmful rests with him. While employment managers select jobs to fit such men as are partially crippled by our schools and environment and engineers attempt to simplify and standardize operations to facilitate industrial training, so far the task of both has been merely corrective in its nature, trying to augment and ameliorate the harm previously done to the men seeking industrial employment.

The third element, environment and surroundings, is no doubt the most pronounced one and even under the existing circumstances may be largely modified if only careful study of causes and effects is made and necessary measures are not in a radical contradiction with existing social-economic tendencies. Evidently, the environment continually exercises its influence on individuals. From the broadest economic, legal and religious relations down to the most trivial manifestations of the everyday life, the conditions of our surroundings help to shape our ideas, aims, prejudices, affect our temperament, determine our relations to men, institutions, etc., in short to define our conduct and bring about self-consciousness. Obviously enough, if a number of individuals living under similar economic conditions, are affected by the same legal status, and observe the same scope of facts and occurrences—the effect of these similar (or even identical) circumstances is bound to produce on all a very similar impression. The interpretation of the meaning and value of these common experiences cannot be much different with individuals as any given social group has had nearly the same sort of education and training and inherited individual characteristics may cause differences only in the degree of reaction. Hence, the psychology, morals and ideas of

men belonging to different social groups are different and to the same group similar. A negro socially isolated cannot think and act as a university graduate or a club man but nearly every Rotarian has ideas, sympathies, manners and habits like those of his fellow from another state. Again, class conscious workmen have more points in common with workmen from other parts of the world than with their own employer or minister of their parish.

The engineers, who by virtue of their work, are in constant and close contact with both these economic classes came to realize the fundamental truth that, with a few single exceptions, the employers and employed do not speak the same language. This mutual understanding was found wanting to such a degree that the leading engineering societies realized the necessity of at least making their own position clear. The unavoidable conclusion that directly pertains to our problem is that the first and most direct task of an industrial manager is to carefully analyze and thoroughly understand the economic status of working class, for on this ground indeed all other forms of social relations are founded.

The Social Aspect

The preceding brief review links together the psychologic and social sides of the question. One cannot be adequately understood without familiarity with the other and, while an industrial administrator is constantly and most vitally concerned with the human side of mastery of production, he cannot avoid floundering in the field of mere reforms unless he clearly grasps the relations between economic causes and idealistic reflections.

The Chamber of Commerce of the United States realized in its turn the necessity of rendering "a new service," which in their own wording reflects the conception that the attitude of employers must be *supported by facts* and adopted by *democratic methods of administration* which means nothing less than the condemnation of old-fashioned haphazard management and substituting for it one based on scientific certainties.

The new service as the Chamber sees it is "to investigate all experiments and developments in industrial relations both in this country and abroad and to place before the membership the results of such research. To assist the constituency of the Chamber in bettering the relationship between employer and employee by making available records of the best experience and practice concerning wage and hours adjustment; methods of handling grievances and

discipline, industrial service (improving the working and living conditions of employees and their families, housing, medical service, recreation, insurance, accident prevention, etc.); dealing with labor organization; utilizing mediation and arbitration in disputes; securing the coöperation of employees in raising standards of efficiency; improving methods of employment management, hiring, transfer and dismissal, fitting the men to the job.

"The permanent results of the activities of this committee will be educational. If successful, it will have created in the minds of the employers a rational attitude, supported by facts and information, concerning the relations between themselves and those whose interests they are administering. The wage-earner is just as dependent upon the intelligent and successful administration of enterprise as is the business upon the loyal and efficient service of the employees. The war has given an impetus toward democratic methods of administration both in public and private enterprise. Industrial administration must adapt itself to those conditions and conform to the prevailing ideas of the time or find itself in antagonistic relationship with all interests with whom it must deal. The employer must conceive himself to be a trustee of the interests of all involved in his enterprise and see that these interests are properly represented, lest he be confronted with opposition handicapping all his efforts. These administrative difficulties are not wholly the product of war nor will they disappear at the close of the war; indeed, it is more likely the industrial problems will increase in complexity with the coming of peace." [81]

One of the most remarkable things that have transpired of late is that the employees both in this country and abroad understand the economic facts and tendencies far better and clearer than most of the captains of industry and finance.

The Economic Aspect

To understand the true nature of the so-called labor problem one cannot avoid a brief review of the economic relations between the employee and the employer. While the one group of society possesses the means necessary to carry on the production, the other owns nothing but the labor-power. The latter of course live only as long as they can sell their capacity to work and can find work only so long as their labor increases the capital.[82]

While a part of slave labor was obviously used to produce enough for their own maintenance, it appeared as if all the slave labor was

unpaid; with a serf-peasant who worked part of the time on the landlord's field and the other part of the time on his allotted farm this division between paid and unpaid labor was clearly separated; in the modern wage system the division became so obscure that a superficial observer is apt to form an opinion that all labor is paid. Manifestly it is not so. Let us take a familiar example of electrical energy; to produce 10,000,000 kilowatt hours the following expenses were incurred:

Operating materials (fuel, etc.)	$ 36,000
Maintenance materials (repair-renewal)	1,400
Fixed charges and money obligations	42,600
Distribution and selling expenses	22,500
Total	$102,500
Gross revenue at 1.5¢ per kilowatt hour (aver.)	150,000
Difference	$ 47,500

Inasmuch as there was no other items of expense except for labor the difference of $47,500 between the value realized by sale and enumerated cost of production is the value that mental and manual labor added in the process of transformation of energy. The actual pay-roll was, however, only $17,500. The $30,000 thus added by labor to the value of electrical energy sold was evidently retained as profit.

In this example, the entire cost of materials and entire other charges reappeared in the value of power. Now, if the labor were paid to the full extent of the value it added to the product there would be no profit in the enterprise. The fact, however, is that the labor-power, as any other commodity is priced not by its use-value but by the cost of its production. The wages, therefore, are determined by the labor-time necessary for production and reproduction of this labor-power.

As in the case of electrical energy, the cost of production of human energy, either mental or physical is composed of three main groups of expenses:

A—Means of subsistence (comparable to operating expense) must be sufficient to maintain the employee in his normal state, that is to reproduce between the working hours the energy discharged while working, by means accepted as standard of living. [83]

B—Reproduction of labor (parallel to maintenance and sinking fund); as men are withdrawn from the use by wear and tear and

death, the labor power must be continually replaced from the ranks of new generation; sufficient means therefore, must be provided to raise and bring up the children.

C—In order that the employee may acquire necessary skill in a given branch of industry, a special education and training is required (similar to fixed charges and administration) and means must be provided to cover the expenses of education and accumulation of experience. Certain margin must also be provided to cover individual's duties toward the state, society and insurance of one kind or another.

Inasmuch as time for production of labor-power is the chief determining element, it is obvious that the employers of wage-earners insisted on buying time. If they had to buy the quantity of brain or muscle energy or result of their work, the difference between the cost of labor-power and its use-value would vanish and profit from the employment would disappear.

The Basis of Wages

Having this point clearly in mind let us glance at special forms of compensating labor. When wage-earners realize that all they are getting is the cost of production of their labor-power they bend their efforts on getting their price in a minimum time. While less than a hundred years ago even children had to work in England sixteen hours a day, the pressure on legislators as well as realization by employers that the less overworked men can produce more and do better work, cut the working day almost in two. The employers, on their part, while yielding to reduction of working hours, attempted to increase the productivity of labor per hour so as to offset the loss in time. The piece-rate payment was introduced with that end in view, but since men are not created equal in their capacity for work some succeeded in earning far in excess of what was considered sufficient for the existing standard of living. Hence, the retrograding and leveling process of cutting down the piece rates to the figure of the average daily wages was resorted to and in this way the most vigorous and skilled men were lowered nearly to the old amount of earnings, though for a larger output, while the less skilled or physically weaker were reduced to starvation wages. The natural consequence was a conscious limitation of productivity of labor.

In the field of power production the day-pay reigned exclusively because there was no convenient piece rate which could be used to rate engineers or firemen. At the same time in this industry, clearer

than in any other, it can be observed that the use-value of labor was never considered as a basis for determining the wages. Let us take a case of two firemen, one generating 1,000 pounds of steam with 100 pounds of coal and another with 150 pounds of the same coal in the same boiler. The first fireman thus consumes eight tons worth forty dollars, while the second uses twelve tons worth sixty dollars and yet both produce the same amount of steam; the first fireman, if paid according to the value of his work should get twenty-four dollars per day and the second only four dollars per day. It is common practice however to pay both the same amount.

In the light of the preceding analysis the wage question appears as a definite problem capable of solution, while the measure advocated by extremists offer no solution but dismiss the question altogether. As soon as workers get the full value of their labor, the wage question ceases to exist, but so does that of profits. So long however, as private ownership and capitalistic regime continue in force, the wages represent only a part of the value added to the product by the labor, the other part remaining in the hands of employers as profits. Formulated by Abraham Lincoln in his speech of 1847: "To secure to each laborer the *whole* product of his labor, or as nearly as possible, is a worthy object of any good government." The first step in this direction is obviously the establishment of the minimum wage scale.

The predominating method of establishing a wage-rate is often erroneously called a "free bargain." It lacked however the element of *freedom* on the part of workmen to refuse unsatisfactory offers and it thus took a form of vulgar exploitation. As a French writer of 1773 puts it, the bargain substantially was carried thus: "Wherever there are large establishments and consequently many day laborers, this is how the (day-rate) wages are naturally established: the workman asks a certain amount, the proprietor proposed a lesser one; and when he adds *'I can get along without you for many days; let us see whether you can stay without me for twenty-four hours,'* then it is clear that the deal is soon closed at a disadvantage to the workman."

Three years after, Adam Smith remarked that "in the long run the workman may be as necessary to his master as his master is to him, *but the necessity is not so immediate*" [84] or as the Federalist puts it [85]: "power over a man's subsistence amounts to a power over his will." Small wonder, therefore, that the individual bargain of necessity gradually gave way to collective bargaining and that labor union; trade unions, and other labor organizations, demanded

the recognition of their right to exercise their skill and power to offset the disadvantage in which an individual worker finds himself facing in the bargain a cunning, experienced foreman, manager or employer who, besides, "can wait."

This right of collective bargaining, gradually being granted by all civilized states, opens two other questions inseparable from it—*the standard rate and the right to a job. The standard rate is only a minimum, never a maximum.* In British unionist practice, where the idea was originated, it merely means that the member agrees not to accept *less* than a certain rate of pay. A large majority of British unions insist on piecework [86] and all the violent criticism that the "standard rate" means "setting a premium on idleness and incapacity," and that it is the "worst kind of communism," etc., was evidently based on misapprehension that the "standard rate" being the *rate of payment* does not fix the actual *amount of earning.* Men of superior skill, even in trades insisting on time work, can give and receive advantage of their capacity and ability by getting jobs that are paid from 10 to 50 per cent above the standard. Furnace building for masons, may be a good example. Similarly in this country we find industrial establishments and power plants which for the purpose of maintaining the highest grade of personnel and, therefore, better standard of production are regularly offering higher wage rates than the union minimum, and with full consent of labor unions involved. We know boiler houses in Massachusetts and New Jersey for example that pay the firemen from 6 to 28 per cent more than the union scale demands.

Considering now at what level this standard rate should be fixed, we must recall our analysis of the three elements constituting the wage as time rate for production and reproduction of labor power. It is not necessary to elaborate here on the subject. Suffice it to remember only that such investigations as were carried by the United States Chamber of Commerce, Federal Trade Commission, War Labor Board and many other institutions and individuals were unanimous in the assertion that a very large portion of industrial undertakings have such inadequate methods of cost finding that they actually do not know what the production cost them. Obviously all the agreements that may be advanced by such concerns as to what they can or cannot pay for labor are utterly without foundation and must not be seriously considered. On the other hand, labor as the opposing party, does not possess any accurate data showing what is the value added by labor to the product. Nevertheless

informations of both kinds are easily obtainable and may readily be calculated. If such *labor value accounting* be practiced broadcast it would furnish the two limits within which all the industrial disputes of wages may be adjusted. If the value added by labor to the product be $47,500 and the actual total wages paid in $17,500, then we know the amplitude within which the adjustments may be made. As long however as owners maintain the policy of secret and inadequate cost keeping, the hit-and-miss method will prevail, and be accompanied by a considerable bitterness in disputes as the room for mistrust and exaggerated suspicions is virtually boundless. The method largely in vogue, as a consequence of this lack of confidence and absence of knowledge, is that of determining a minimum (or average) cost of living for a trade, under accepted conditions, time and place. Any agreement reached on such a basis is individually unsatisfactory inasmuch as it is based on an average, and socially harmful as it necessarily *retards the advance in wages until after the cost of living has already increased.* The two outstanding results, well known to all, are first a lowering of the physical and intellectual standard of the nation[87] and second, a decrease in productivity of labor. Professor A. Marshall observed this fact some twenty years ago and summed it thus.[88]

"We may conclude in opposition to the older economists, (W. N. P.) that any change in the distribution of wealth which gives more to the wage-receivers and less to the capitalists is likely, other things being equal, *to hasten the increase of material production,* and that it will not perceptibly retard the storing up of material wealth." Since this has been written the work of notable engineers in industrial administration proved in cases of thousands of plants that *low wages and high efficiency are never met in reality* while increase in wages is coincident with increased productivity or improved quality of work. The leading English trade unionist gives an interesting resume, linking together both sides of the question: "Considering, therefore, . . . that an increase of wages is likely positively to increase that highly productive form of the nation's capital—the physical strength and mental training of the manual working class; that the middle class is mainly bent on securing permanent incomes for future maintenance, and will therefore be induced to work no longer and harder, and save more, the lower the rate of interest descends; that a low rate of interest both stimulates inventions and promotes their general adoption; and that municipal

and national enterprise, if favoured by a low rate of interest, grows by leaps and bounds, economists are beginning to assert that a rise of wages at the expense of profit would probably result, not in less, but actually in more being produced, and taking all forms of national wealth into account, that it might be expected positively to increase the productive capital of the community in one form or another." Let it be said in passing that, as applied to the power industry of this country, the chances of the necessity of reducing the rate of interest are infinitely remote, so long as the amount of preventable waste, particularly these due to poor methods of operation and management, are still many times larger than the present cumulative payroll. We do not need to dwell on this subject of standard rate any longer; for our purpose it suffice to note that (1) it means *rate* not *total earning,* (2) so long as wage system remains in force it is possible on the basis of accurate knowledge of "value added by labor" to determine the limits for its adjustment (3) that it is to the advantage of the industry and of the nation to fix the standard rate at the highest practicable point, but (4) inasmuch as standard rate is merely a rate (per hour or per piece) and the other factors may not be definitely determined (overtime, special skill, unusual physique, etc.), the standard rate should be accepted only as a basis or guaranteed minimum rate of earning while a secondary rate shall be applied over and above this primary rate. This will be discussed later under the heading Two Rate Wages.

Incentive Payments

A variety of schemes and plans have been proposed and tried by different authors with the end in view of establishing an adequate basis for labor compensation and a stimulation for higher quality work. Before we briefly review them one point of great importance should be clearly established: *in the production of power the quantity of the plant's output is independent from the worker* and therefore the incentive may in general be based only upon the *quality of the work.* The success or failure of any such attempt depends therefore upon the recognition of this principle and the method of measuring the quality.[89]

It has been an invariable experience of all concerns attempting to base an incentive for more or for better work either on *factors independent from the employees or on arbitrary and*

loosely established methods of measurement, that the results were either short lived or unsuccessful from the start. As long as we admit the fact of inequality of skill and corresponding inequality of value of labor we are facing a new problem. Should the labor power or superior skill be permanently rated at a higher figure or should it vary as this skill makes itself manifest? Obviously the question in this form confuses two distinct propositions. In every trade and at any time there is a certain accepted average skill qualifying the man to do his work. In this sense the difference between the values of labor-power of a window cleaner and fireman is permanent. Opposed to that we observe a difference between two window cleaners; one, of superior skill, can wash equally well three times as much glass surface as another and yet consume no more time or supplies. Again, one fireman, due to his superior skill in selecting, and maintaining the more favorable conditions, can produce the same amount of steam of the same quality and pressure with less fuel than another. The moment we pay both men the same wages, we underpay the man of superior skill. Should we then decide to increase his *rate* according to his additional dexterity, we pay not for what *we receive* but merely for what *he possesses.* In other words, whereas difference in value of labor engaged in different occupations remains permanent, as long as there is a difference in general requirement of the work, the difference based on the degree of skill, in the same occupation, is manifest only when actually exercised.

The inevitable conclusion thus arrived at is that *any degree of skill above the average in a given trade or occupation must be actually measured each time as it applied.* The price paid for such surplus skill is the bonus or secondary wage rate, paid over and above the wage rate accepted for the labor power in the given trade or occupation.

To assist the employees to acquire the highest possible degree of skill, as it will be shown later, is a specific function of management. Those who acquire the skill and the habit of applying[90] it to their work are entitled to an extra payment which thus appears as a reward to those who learn, while it is really nothing else but the *value of additional service rendered.* It is appropriate at this juncture to note the fact that if the expenses of acquiring this additional skill (comparable to the revenue producing investment) are shared by the employer providing for the training and education of the employees, his claim for

a share of added value of labor is warranted, while in the case of a simple request of doing more or better work without actually assisting the men to that end, employers claims are questionable. The men usually realize this distinction very clearly and similar ways of reasoning are often heard among those wielding shovels and a thorough training and full coöperation on the part of management offers the strongest argumentation in favor of adequate and correctly established method of bonus payment.[80]

The antiquated, unscientific way of thinking is responsible for the misconception on the subject of wages common to many employers and labor organizations. While some economists obstinately insisted that the profit is not due to the difference between the value of the labor and its price as a commodity but to some miraculous process of autogeneration of capital, some labor organizations, protecting the minimum wage scale, raise all kinds of objections against higher pay to more skilled members. The "equal pay" error however shall have no place in the industry based on wage-system. As we have shown before, *the right of the producers is proportionate to the amount and quality of work they furnish; the equality therefore consists in that the labor is measured by an equal standard.*

The special feature of the two-rate payment will be dealt with at length later, suffice it to say now that while this method of payment for services rendered has a basis a guaranteed amount (at least equal to the accepted standard daily wage or minimum wage rate), insuring the adequate living expenses, the supplementary payment is commensurate to the value of the services rendered. *This principle establishes equality as far as the bonus is measured by a definitely established task.* Moreover, in power houses there is no room for objection to "speeding up," "undermining the health," etc., for the simple reason that better work or higher efficiency is attained *only* when the amount of physical work is reduced. In other words, higher efficiency of firemen means less coal handled and burned for the same output, less ashes removed, etc. Higher efficiency of engineers or switchboard operators means merely closer attention to the instrument showing the distribution of load, vacuum, etc., resulting in smaller steam consumption. Higher efficiency of maintenance men similarly means reduced work under strenuous conditions of emergency repair which is displaced by preplanned inspections, scheduled overhauling, etc. These principles clearly established, it is comparatively easy to trace the typical fallacies

prevalent in the various modes of paying to the power plant employees and in the variously called additions to their regular wages.

Practically all of these methods were devised to stimulate the employees to do better work and to relieve the management of the responsibility for training and guiding the men. The improper methods unfortunately are used often enough to discredit the correct underlying principles in the eyes of those who do not care to study the question in its entirety, be it owners, managers, or the laboring men. For the sake of simplicity all these plans, as practiced in the power plant work, may be classified into four principal groups:

1 Profit sharing
2 Premium plans
3 Rewarding individual efforts
4 Two-rate wages.

Profit Sharing

Profit sharing and co-partnership of labor with capital was perhaps the oldest attempt to secure the workmen's consent for higher prices and profits. It received favorable attention from philanthropists and social reformers and in 1892 there was formed in this country the Association for the Promotion of Profit Sharing; in France a similar society was organized in 1879 under the name Société pour l'Etude de la Participation aux Bénéfices. The British Board of Trade defines these as follows: "profit sharing is understood to involve an agreement between an employer and his work people under which the latter receive, in addition to their wages, a share fixed beforehand, in the profits of the undertaking." [91]

There are, however, many varieties of the scheme that cannot be fully covered by this definition; for instance under Youngstown Sheet and Tube Company's plan the percentage of bonus to wages was not announced in advance but remained entirely at the company's discretion. This plan was abandoned after the violent labor outbreaks experienced by this corporation in 1916. [92] The head of another profit sharing concern writes: "On January 1st of each year our profits are distributed, and wages adjusted. On that day we consider the question of the wages of employees. *Any who insist on securing an advance in*

salary are dropped from the profit sharing list." (The italics are ours.) The president of another corporation expressed himself thus: "My idea is to pay men as regular wages *an amount slightly less than the actual value of their services,* and then to make an additional payment to them, dependent in amount upon the success of the business. . . ."

Again, some, like the A. W. Burritt Company, of Bridgeport, Conn., cause men to lose "coming and going." Mr. Burritt, the treasurer of the company, states in his book on profit sharing that "for the purpose of providing a fund from which to meet losses, ten per cent of the wages of participating employees is deducted from the weekly pay envelope." Again, as in the cases of the Ford Company and a contracting firm in Ohio, the profit sharing is applied only to "such employees as *may be deemed worthy* by the Board of Directors."

Like all paternalistic, arbitrary measures emanating from "above," whether prompted by charitable and "humanitarian" motives or, as it is more frequently, by business considerations such profit sharing plans are bound to be distasteful to organized and conscious labor. The cardinal objection is against the demoralizing effect of either "charity" or "bribe," as the case might be, concealed in such sharing of spoils. Both are calculated to shade off the real relations and tame labor to eat from the hand and then kiss it. From the stand taken on the subject by the Federalist and some of the trade union leaders there could be no resentment expected to any *supplement* to the wages after the standard wage scale, approved by union as has been secured, hours and conditions of work regulated, etc., but, the distribution of stock or cash-profits is usually connected with so many discriminations, conditions, and even compulsions, that there is always present in the workman's mind a fear that these schemes are calculated not only to make him, in anticipation of his possible share of profit, more docile and tolerable to the conditions otherwise unbearable, but moreover, to enslave him by compulsory application of his money to real estate, shares, etc. Again, the advocates of profit-sharing schemes themselves admit that these plans are introduced for the purpose of (1) cutting down standard wages, (2) of discouraging demands and preventing strikes, and (3) of preventing the employees from accepting better employment elsewhere after his money are tied up with a concern. Moreover, paternalistic profit sharing not infrequently makes the distribution of shares subject to examination of family relations, private

mode of living, moral character, etc., thus depriving some of the employees of their last vestige of self-respect and independence.

The practitioners of profit sharing themselves do not believe "that in groups of large size it will normally operate as a strong incentive to personal efficiency, increased effort, care, economies or coöperation." [91] They even go as far as to admit that "this aim can be reached much more directly, simply and surely by putting the additional amounts in the regular pay envelope." [92]

How then can profit-sharing promote industrial peace and efficiency? The advocates of these plans give answer: "freedom from strikes should rest upon (1) fair wages, (2) good conditions of employment, (3) considerate treatment, (4) deserved loyalty, and (5) recognition of efficient service." [93] Looking over these five conditions we fail to see any connection between them and the principles of profit sharing; indeed any labor organization may accept these conditions for its own platform and the truth is that the truth is not told.

The application of profit-sharing schemes in the power industry, after this general review, presents to us a specific interest. The Brooklyn Edison Illuminating Company pays a "wage dividend" which is a percentage upon the employees annual earnings, varying directly with the rate of dividends paid upon capital stock for the year, and with the employee's length of service. *These dividends are credited toward the purchase of the company's stock.* Of the gas companies using profit-sharing plans in the United States we know of New Haven Gas Light Company, the Boston Consolidated Gas Company, and the Grand Rapids Gas Light Company. The first mentioned concern like the Brooklyn Edison Illuminating Company credits quarterly wage dividends to an employee until the amount is equal to a share; the certificate is then issued to him. The second concern actually pays the share of profit on the same rate as upon shares. The last mentioned company uses "sliding" scale, similar to the one in operation by South Metropolitan Gas Company of England, under which the rates increases with the decrease of the price of gas. In 1915 less than 6 per cent of the shares were held by profit-sharers, thus indicating that the whole plan is bordering on a myth.

It is interesting to note that the use of profit-sharing instead of bonus in power industry is made because of alleged *"difficulty or impossibility"* of measuring the tasks of stokers, enginemen, gas fitters, meter readers, etc., the experiences of the author and of other engineers, notwithstanding. The conclusion therefore cannot

be escaped that unfamiliarity of management with the managerial tasks and the development of the science and art is more likely to be the cause.

Researches made by the United States Labor Department and by private investigators show one more instructive peculiarity of these schemes. Nearly all establishments once adopting profit-sharing abandon it in a very short time, the exception being the cases in which the profit sharers are not the *producers* but *officers* or the salaried employees. The explanation of this fact is obvious and illustrates an utter futility of expectation that profit-sharing may unite the interests of employed and their employers. Profit sharing, being based on the rate of profit, depends upon the success of business transactions, not on efficiency of workmen alone. Indeed, the management buying unsuitable or expensive materials, hiring low-paid labor, increasing over-head expenses, etc., may wipe out all the economies that employees could effect. Moreover, increasing profits one way or another, indicates that the commodity (power or gas) is sold not only at a price which is higher than the cost but that this difference is increased. In other words, such success means increased cost of living (or at least not reduced) while the increase of wages represent only a percentage of this increase. Thus the profit sharing is based on an economically unsound principle. Evidently those employees whose duty is to secure larger profits may feel that the share of profits is theirs by right while those whose function it is to produce the goods, resent it as it is more to their advantage to see the prices go down than the profits to go up.

Broadly speaking, while any plan to give the employees the *privilege* of sharing the company's profits aims at instilling the spirit of unity of interests of employer and employed, it fails because this privilege is not conditioned by responsibility of jointly managing the affairs of the enterprise. So long as the form of directing and controlling the affairs of the enterprise remain autocratic, even though it may be benevolent and paternalistic, the employees clearly realize their inability to participate materially in securing the success of the enterprise and to render service to the community. Such mutuality of interests could rightfully be expected if the employees had the opportunity to control all functions of management, fix the salaries of directors, direct purchases, investments, sales and generally have a hand in all financial transactions. But then the organization would become cartel or coöperative and the "profit sharing" will lose its identity, workmen would receive full value of their labor and not merely share it with employers.

As long as they are expected, however, to work under the conditions provided by the management, serving the interests of the owners, using the equipment and materials furnished by the employers, who in turn disposes of the product, and carries out all outside negotiations without the counsel and consent of the employee, the profit and loss of the enterprise is influenced only in a very slight degree by the excellence of the work done by the men. If for any reason whatever dividends are not declared, the workmen lose their share, perhaps through no fault of their own, since even if they have been working as well as possible, blunders in policy and mismanagement, overequipment, idle charges, stock gambling and what not, could easily offset any advantage of the splendid efforts of the men.

Nevertheless there are instances on record showing both financial success and freedom of internal friction in the companies adopting profit sharing plans of compensating employees. These however are easily traced to the more direct and unquestionable value of higher wage scale and more sincere interest in the well being of the employees, and not to profit sharing proper. In fact there is a much larger number of cases on record where the profit sharing plan unaccompanied by guaranteed high pay and welfare work caused endless troubles, discontent and even strikes. Particularly unfortunate experience in this respect were had by companies forcing their employees to invest their share of profits into shares, real estate, etc. In all cases, however, the profit, being not necessarily the result of good work of men, has little to do with direct stimulation for learning the best way of doing the work and acquiring the habits of industry.

Premium Plans

The first attempt conducted on a large scale in this country to secure operating economies in power plants was made about fifteen years ago on the Atchison, Topeka and Santa Fe Railraod. The primitive method used is of interest chiefly by way of contrast with the development in the art. It was recognized that:

1 The actual performance was worse than the possible

2 Local conditions of various plants call for different standards.

The work of establishing standards of performance was based not on actual experiments, but on average statistical data of the past, reduced by the guessed percentage suspected as waste. Then an allotment was made for each individual plant as to how much

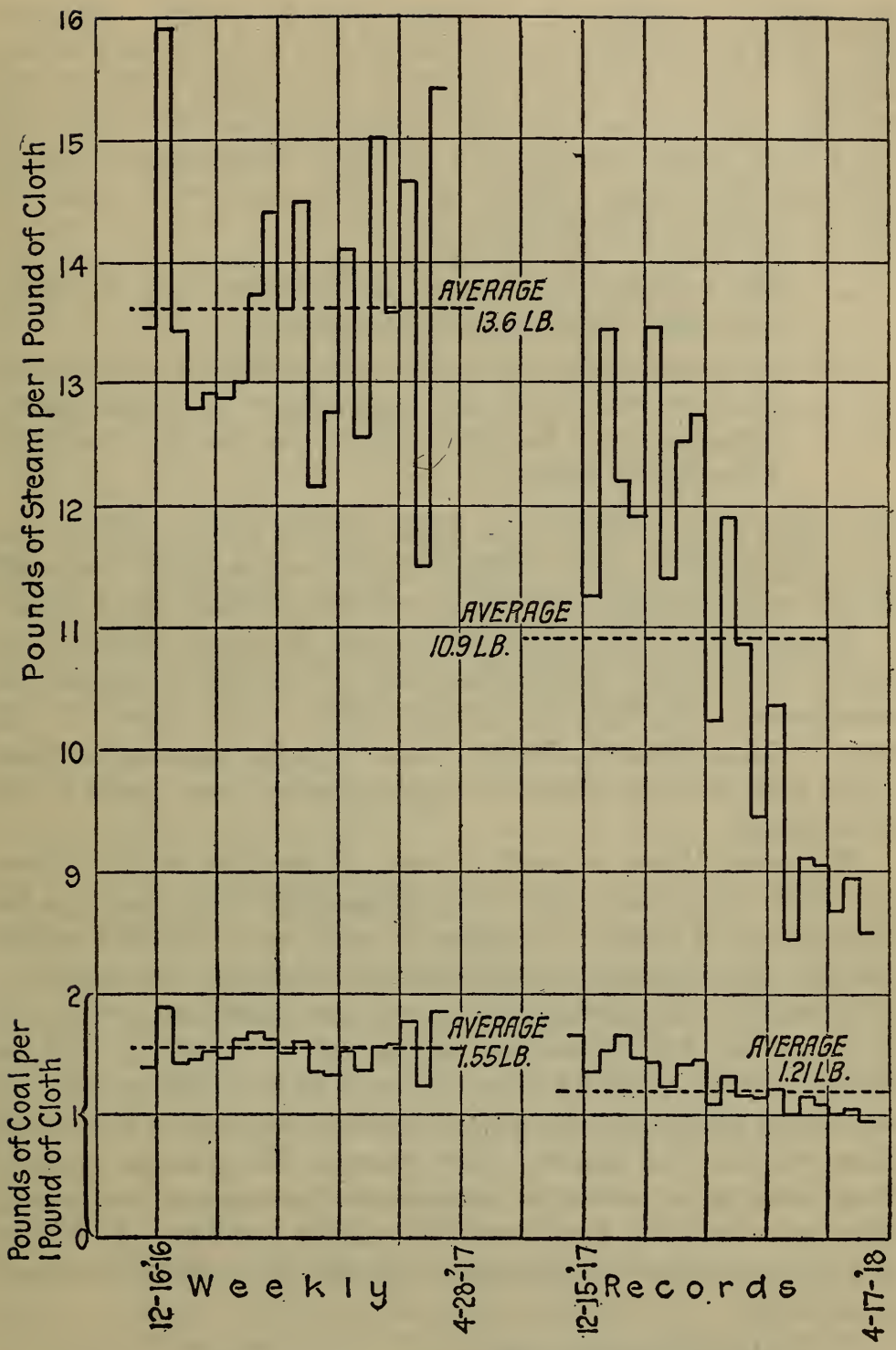


FIG. 56.—STEAM AND COAL CONSUMPTION PER POUND OF CLOTH BLEACHED

Attempts to judge the quality of work of firemen by mixing it with variable factor of how steam is used in process is an absurd misconception. In this case steam consumption per pound of cloth was reduced 19.8% while coal consumption was reduced 21.9%. In fact the steam production per one pound of coal increased 2.86%.

fuel should reasonably be consumed there per month. Similarly pay-rolls were revised and certain labor costs were assumed as reasonable. These two records multiplied by constants arbitrarily set (six for fuel and four for labor) added together and divided by ten give the figure of merit used as a basis for payment of bonus, the bonus itself being adjusted on a sliding scale. The shortcomings of this crude method are apparent:

1 Men were left to discover for themselves how to secure the results desired by the management
2 The management, shifting the responsibility to the men, was itself uncertain as to the exact amount of saving accomplishable due to individual efforts, and therefore could not fix a definite bonus.

The results accomplished by the Santa Fe men were, however, sufficiently satisfactory to the railroad so that not burdening itself with further responsibilities, the management still maintains this method."

Numerous other attempts were made by other concerns producing power, either for their own use or for sale, to organize the management along lines more definite than a mere request "to do better." Inasmuch as the largest portion of power operating expense is for fuel, the first efforts to secure economy were made in the boiler plants.

The resemblance to profit sharing is manifest in the Edison and Lewis "premium" schemes for power plant force based on the ultimate cost of power. A number of years ago a Portland cement company put the firemen, mostly skilled, industrious Portuguese on a "premium" plan whereby their work was judged by the cost of steam generated and premium offered for its reduction. To no surprise on our part, the scheme proved to be a failure and was abandoned, chiefly upon insistence of the men themselves who clearly conceived what the inventor failed to see. The common error of all premium plans is that the financial result or cost of operation is taken as a basis for award or denial of the premium. It fails in this way to take due cognizance of the fact that the cost is affected by:

1 Price of materials used
2 Quality of materials used
3 Maintenance of equipment
4 Load characteristic
5 Volume of output
6 Managerial methods.

Obviously the first five factors are not under the control of the firemen, engineers, laborers or switchboard operators, and even the plant superintendent seldom has full charge of these conditions, therefore any attempt to judge the work of operating men from the viewpoint of costs is a shortsighted placing of responsibility where it does not belong. Furthermore, wherever only operating factors are taken into consideration, the determination of premiums for the entire personnel does not differentiate among shifts, crews or men; yet it is quite evident that the extent to which different employees contribute to the attainment of economical results is very unequal. While firemen can cause as much as a 50 per cent fluctuation of fuel consumption per unit of output, all the rest of the power plant employees could influence the operating cost but slightly.

A similar misconception caused by insufficient familiarity with facts is manifest in a recent application of a premium plan to a bleachery plant by Mr. Lewis. Fixing premiums on the basis of power consumed per unit of manufactured output means working on the wrong premises inasmuch as the perfection of power generation is thus inseparably mixed with the efficiency of:

1 Power distribution
2 Manufacturing equipment
3 Bleaching processes
4 Kinds of goods handled
5 Amount of finished goods.

Figure 56 illustrates an actual case from our practice of steam and coal consumption per pound of cloth bleached. The reduction observed does not in any way reflect on the efficiency of the boiler room operation and there can be no reason why the firemen should receive a premium if the saving is due to the improvements in distribution and use of steam, stopping the leaks, etc., nor to lose it, because the bleach house foreman does poor work. Such short-cuts largely contribute to bringing into disrepute the schemes of paying premiums without analysing the responsibility for the contributing factors. Similar method has been practiced by the T. M. E. R. & L. Co., of Milwaukee, Wis. The commendable feature of all these efforts is not however in themselves but in the fact that more than the usual amount of attention is paid to both operating and managerial problems. The deplorable part of this premium, or as they call it "bonus," plan is the inseparable confusion of records and bonuses of various employees—individually and by groups. The result is that while firemen and maintenance men may do excep-

tionally meritorious work, reaching very high efficiency, the inattentiveness of an engineer may raise the steam consumption. Yet, instead of allocating this responsibility, the good and bad work is thrown in one pot, mixed, stirred up and, if the plant's average is below the mark *all* lose the bonus, good workers as well as negligent ones. The company calls it "all for one, one for all" while to us it looks like Sodom and Gomorrah being punished for one sinner instead of one Lot spared. Economically the results reported were meager. Under this plan, during the best year on record employees earned only about 7.5 per cent as bonus over the regular wages.[95]

Rewarding Individual Efforts

The principle of rewarding men for their efforts in securing operating economy and improving methods, while sometimes bringing about a measure of improvement, cannot and never does accomplish in full measure the elimination of preventable wastes. Such failure is primarily due to the "gentleman's understanding" that the firemen and coal passers know more about science and practice of economical operation than the engineering staff and the management. *When the men are simply told "to do better" and left alone* to struggle and solve the problem, in order to receive a promised reward, it is a sign of weakness of the administration, *a case when the management fails to manage.*

Another reason why this plan fails to produce better results lays in the fact that although the management shifts the responsibility for securing better results on the men, it does not likewise give the necessary authority to adjust and control all influential factors. Men cannot alter the conditions under which they are expected to produce results. Men seldom have sufficient power of reasoning for detecting the harmful causes. Men never have enough time and facilities to analyze, plan and adjust the conditions the way they should be, and if they can and do, then the nominal management becomes simply an ornamental adjunct of the organization.

The previously cited Santa-Fe bonus has all the ear-marks of the method of rewarding individual efforts. More recent attempts are exemplified by O'Neill's method [96] and the practice of the Manilla Electric Company.[97] The most frequent error however in the application of this reward system is in the arbitrary selection of one or more isolated factors, like high CO_2 in the flue gas, low carbon content in ashes and so forth, and rewarding men for obtaining these

fragmentary results. The interrelation of plurality of factors is for simplicity's sake overlooked and the final results are frequently more unsatisfactory than before.

In the author's paper on Bonus for Firemen[98] he maintained that "if one of the advocates of these short cuts would take pains to investigate any of his hobbies, whether high CO_2 or low flue temperature or good ashes, or anything else that can be studied, he would find that the complexity of influential factors is sufficient to warrant a long step toward detail study." Five years later *Power* published an article describing Mr. H. O'Neill's method of determining bonuses for boiler plant operatives based on the combination of the three above mentioned factors. Some day, we hope, another revelation will be made announcing that "something else" is to be taken into consideration. The pathos of this plan however is reached with the announcement that "the division of the bonuses to individual men is *left to the judgment of the management.*" A truly frank admission that the management is not based on the facts but on opinions and does not know how to measure accurately the contributing effect of the work of firemen, cleaners, repair-men, etc.

A step forward in this direction has been made at the Manilla Railway and Light Company's plant where the proportion of bonus received by each "varies with their responsibility or the degree in which their duties offer an *opportunity* to save coal." Whether the opportunity was actually exercised, remains however uncertain. In accordance with Blaisdell's plan a water tender receives 10 points, a fireman 6 points, an oiler or coal passer 3 points, etc., but, similarly to the Santa Fe case, there is no definite reason why such an arbitrary favoritism should not be challenged. While Blaisdell's method is based on the most unfit principle of dumping without analysis all causes and all individuals reckoning the efficiency of all stages of the process of power transformation and generation in the final terms of thermal efficiency (number of B. t. u. per kilowatt hour on switchboard) and finally apportioning the spoils of this battle royal for efficiency at fanciful ratios, there is still another factor deserving a mention. The competition among the members of a "watch" is not encouraged because of impossibility created by the tact that only the final all-around efficiency is measured. But the rivalry between the three "watches" is fostered to the extent that the best gang takes away from the others ten per cent of their bonuses. This forfeiture of earned bonuses discloses another dangerous weakness of the entire plan. If one gang has accomplished results en-

titling it to a deserved reward, so does the other gang that exceeds the requirements. If however, certain results should entitle men to a higher reward than some others, the gradation of rewards according to results should be fixed permanently. As it is, the same quality of work fetches different compensation not only in comparison with another gang, but the same quality of work of the same men may fetch different rewards on different days. In other words, if a value of a "good" work is depreciated by comparison with the "better" work, it means that the whole system lacks clear conception as to what constitutes the task and what it is worth.[99]

Two-Rate Wages

About ten years ago the author published some data from his experiences with payment of two-rate wages in connection with accurate measurement of the quality of work done in the power houses. It attracted an unusual amount of attention and favorable comments from most diverse quarters and the method became known, in parallel with practices in other industries, as task work with bonus, although special peculiarities of power industry, substitution of quality requirement for this of quantity for a task, payment independent of the time in which the task was fulfilled and number of other dissimilarities made the name ill-adapted and non-descriptive of the fundamental principles involved. Substantially the original plan was described thus:

The well-known falling short of test results in every day performance can be eliminated or at least greatly reduced and uniformly high efficiency obtained in regular service. In order that the favorable conditions be maintained and the desired results of high economy of operation be accomplished not spasmodically, but day in and day out, the task based on quality ought to be *possible* and *desirable*.

The possibility of accomplishment of task is governed by (1) proper coördination of conditions and supplies with power demand and existing facilities; (2) proper assistance to men in their work; and (3) proper balance of strain during the work and regain of physical losses of the individual during intervals between working periods. It complements the common method of time studies, with a new method of physical studies of the effect of work on the health of workingmen and a method of scientific determination of length of working day.

The desirability of accomplishment of a task set within men's

possibilities requires the study of (1) physical stimuli, (2) psychical stimuli, and (3) social stimuli. To the first group is referred extra payment, better surroundings, shorter hours, sanitary conditions, etc. To the second group factors like sporting spirit, confidence in

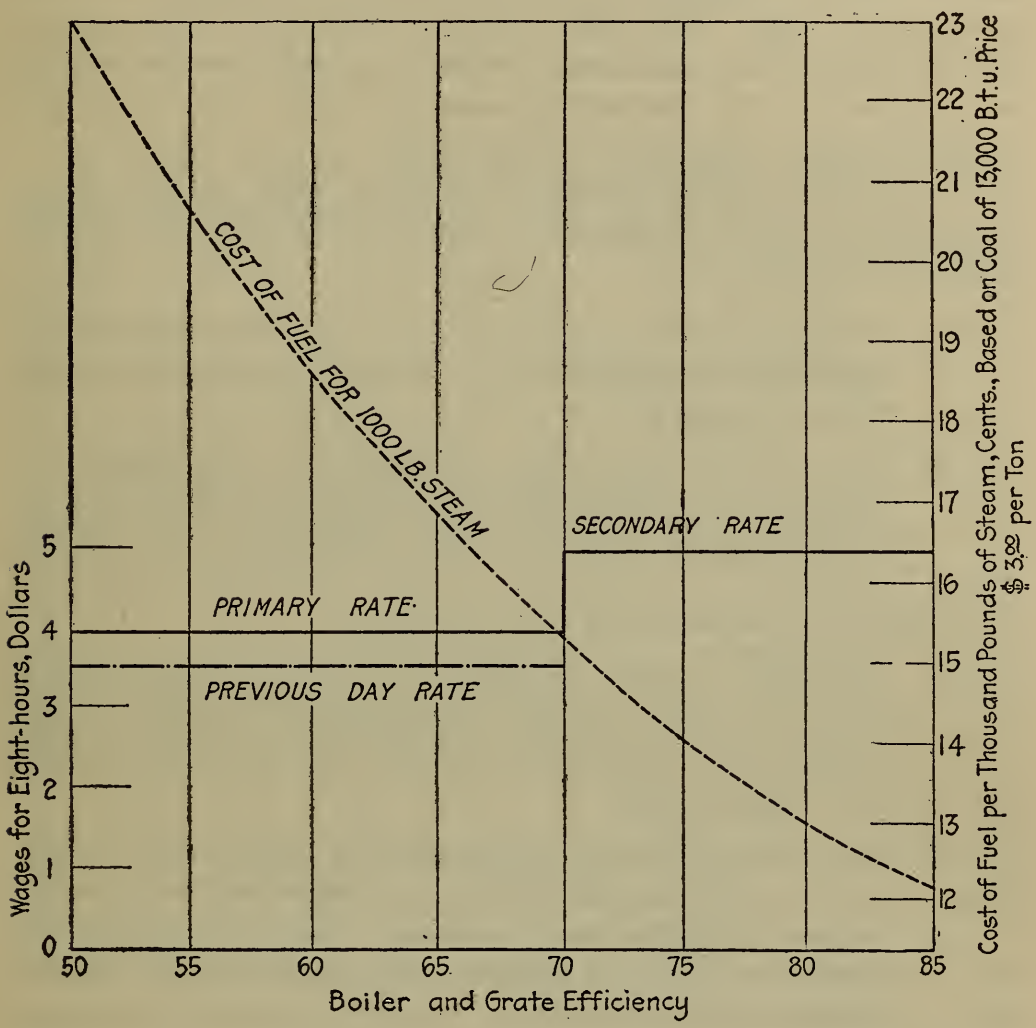


FIG. 57.—RELATION BETWEEN SECONDARY RATE OF WAGES AND COST OF PRODUCTION

In a given plant, the task was set to attain 70% boiler and grate efficiency. For the work below this standard firemen were to receive $4.00 per day, and the cost of fuel per thousand pounds of steam was 15.3c. or more. When the task is accomplished, a secondary rate, equal to 10 c. per hour, was paid over and above the primary rate. The cost of fuel per thousand pounds of steam under this condition is below 15.3c. (Cost and wages on this chart are on pre-war basis.)

records, relationship with management, desire to study and advance, etc., and to the last group belong such stimuli (favorable or not) as attitude of fellow workmen, of trade unions, of members of the family, and condition of labor market, legal regulations, etc.

Reviewing the present status of the incentive and bonus payments before the convention of delegates of the National Association of Stationary Engineers in 1919 at Huntingdon, W. Va., the author presented for the consideration of that representative and influential body a plan, as practiced by him for a number of years and called the two-rate wage. This plan received a most hearty approval as was indicated by the unanimous vote that a pamphlet on the subject be published by the National Association of Stationary Engineers for distribution among power-plant owners.

The features distinguishing the two-rate wage payment from any other form of compensation or wages are based on two fundamental conceptions:

1 *Guarantees* to every member of the organization rendering specially valuable service, a reward proportional to the service rendered

2 *Service to the community,* understood as responsibility to run industry democratically and efficiently, thus rendering socially necessary service with minimum waste of any kind.

From this a practical plan is evolved that:

1 *Guarantees* to every member of the organization rendering useful service a standard compensation (primary rate) sufficient for maintaining a decent and comfortable mode of living and that

2 *Offers* an opportunity to secure extra reward for valuable service resulting in elimination of industrial waste in the form of additional wage (secondary rate) and an advancement to a position of a leader helping to further the socially valuable, efficient service.

The economic consequence of this method may be well presented in this chain of sequences:

1 Increased earning (secondary rate) of the wage-earners does not increase the cost of living as this addition to wage is only a portion of the reduction in cost of production

2 Reduced cost of power stimulates its broader use

3 The larger the use of power in industry per man the higher is the earning capacity of industrial workers

4 With increased earnings of the wage earning class, their purchasing (and consuming) capacity increases

5 With increased purchasing capacity of the people, the demand for goods increases

6 Increased demand stimulates production to satisfy same (provided it is not abused by a combine to advance prices or secure special privileges) and therefore

7 Increased industrial activity in order to meet the demand provides employment for unemployed.

Benjamin Franklin, discussing the very heavy burden of taxation at that time stated that our losses due to idleness cost us twice as much, while those caused by lack of knowledge and poor methods produce four times greater suffering. If that was true in his days, it is indeed, more so in our time. Anyone familiar with our industrial organization knows that in most of the establishments not over half of the productive equipment is actually used and when used it is operated with something like half of its efficiency. During the war, the industries here and abroad, despite the shortage of men, despite poor organization and frequently utterly inexperienced in methods and processes, produced a great deal more than either before or after. The reason for the wartime increased productivity was plainly in the almost unlimited demand for "war-essentials" at high prices. The manufacturers were thus induced to spur up production to reap lavish profits while the workmen were stimulated by patriotic desire to make the word "safe for democracy" and to see it a "better place to live in." As the old joke goes "whether the life is worth living—depends upon the liver," but as we all know the "liver" itself depends on the stomach, which in turn depends on the pocket. Hence our problem of making life worth living.

Lord Leverhulme, the world's foremost manufacturer who acquired an enormous fortune and a title through a solution of the labor problems in his plants, defines them thus: "The chief of these basic principles are increased production with consequent reduction of overhead charges and reduced operating costs combined with shorter hours for workers, resulting in better working conditions, leading to greater efficiency and producing higher wages and better profits."

To lead the way toward the realization to these conditions, no other group of men is better fitted than the engineers and to begin the work no industry is better adapted than this of power production. Power industry is the fundamental one, upon which all and every industrial activity depends, including a great portion of transportation. Disruption of power production throws men out of work and

into untold misery and suffering, while abundance of cheap power is the very foundation of prosperity and progress; moreover, as the British Interim Report on Electric Power Situation shows, the wages are highest in these industries that use most power per workman.

The conditions we were accustomed to actually see in the industry seem to discourage optimism and the examples of Ford and Leverhulme were sometimes pointed out as exceptions proving the rule. The increased production was regarded by manufacturers with fear, lest overproduction bring to a smash the market prices; the increased efficiency was not considered desirable so long as profits could be made over and above actual waste; and long hours and low wages were considered essential for profit making. To-day even the most conservative of them are forced to admit that we never had an overproduction of goods, and panics and depressions were due to inability of low paid labor to buy enough to satisfy their needs and wants.[100] The fear of overproduction thus waning, it is getting clear that greater production, by reducing the overhead, and charges on partly idle plants, helps in reducing the cost of production; similarly, greater efficiency is being sought to further reduce manufacturing expenses and it is being realized that this greater efficiency is incompatible with low paid, fatigued, dissatisfied help. Thus larger output at reduced cost could be sold cheaper, while better paid workmen can consume more than heretofore under the reverse conditions.

The industrial system, thus modified, receives a new lease on life. The author does not claim, of course, that a millennium is thus at the door, neither that this new regime is permanent, but the social stability may be improved considerably even though perfect harmony of interests is still distant. A further step becomes inevitable, for so long as individual competition among establishments remains, the aim will be *profit,* not *service.* In other words, while greater productivity and higher efficiency became indispensable, under individual profit-making regime, efficiency is still measured in dollars, not in efforts and resources conserved. To burn molasses under boilers in Cuban plants is profitable but it destroys our food resource; to put in use abandoned United States Army trucks, automobiles and tires would have been efficient but it meant loss of business to French manufacturers; to devise a plan of coöperation between central stations and isolated plnats would be beneficial to the communities, would conserve fuel and develop very high efficiency but it may curtail the profit-making of central stations interests.

Now, considering these limitations imposed by transient conditions of the period of reconstruction, it becomes at once evident that the first step is that of revision of the time-honored wage basis and all its latest ameliorations, profit sharing, individual reward or any variety of so-called bonus systems.

The head of the Interboro Rapid Transit Company for some time, quite unmolested by censorship and by Postmaster General, has conducted radical propaganda. The gist of it is that while the cost of some supplies increased lately over 100 per cent and the cost of coal increased 84 per cent, the increase in wages was only 62 per cent. He candidly adds that the company was "glad" to grant this 62 per cent raise and we have no reason to doubt the veracity of their rejoicing over this economy of some 40 per cent on the payroll. The lesson to be derived from this cynical example is simple and important. *It illustrates the fact that the increase of wages is always slower than that of the cost of living.* Moreover, it forcibly puts before us the problems of conservation of human race. Percent of rejections from the army draft because of physical and mental deficiency was so high as to question whether the earnings and condition of work do not gradually undermine the health of the Nation. The demands of organized labor for the recognition of standard wage scale appears therefore not only warranted but even inadequate for it leaves out any specific provisions for exceeding this scale, which in its very nature could not be anything but a minimum.

The premises upon which the wage system tries to establish the daily earning is that of absolute minimum of the cost of existence. The theory of "free bargain" evidently does not hold water as the individual worker, unlike his employer has no other means of subsistence but the sale of his labor-power. He evidently cannot wait long to induce the employer to raise the offer and must accept nearly any figure offered. Collective bargaining, lately sanctioned by the government, in several instances ameliorates this condition but does not reach the bottom of the issue. The point the author desires to make clear is that the wage or rather minimum wage is to be expended by workmen in three distinct directions:

1 To buy meals, shelter, and clothing as necessary to restore the vital energy spent during his work for his employer

2 To secure for his family an income adequate to maintain the accepted mode of living and to raise children that are to replace him on labor market when he himself is worn out

3 To meet the obligations imposed on him by society, by government and by morals, i. e., to be able to pay taxes, dues, insurance, put up savings and maintain decency in his mode of living.

There is in reality a fourth, and very important group of expenses, namely, *expenses of acquisition of skill.*

Obviously, in order to learn a trade or profession certain amount of money (time and efforts) must be spent both by a man himself and by his parents. The higher is the degree of skill to be obtained or the more complicated is the study, the larger is the expense and the longer the period of training. Moreover, higher intellectual development and success in attaining expertness require more comfortable surroundings, more regulated, refined mode of living and as a consequence it creates higher desires for recreation not in mere relaxation but in enjoyment of art, etc. In other words a higher degree of civilized life both precedes and follows the development of a more efficient, intelligent, productive type of man. This class of expenses is generally neglected when wages are considered and receive a measure of recognition only in cases of leading salaried positions.

Yet, in case of any manual worker it is just as true that to *develop* his laboring power and acquire a given skill, certain amount of values must be spent. Therefore, *as the costs of producing laboring powers of different quality differs, so must the value of the laboring powers differ.* Consequently, different values of laboring power *must fetch different wages on the labor market.*

While the truth of this proposition as regards different trades and occupations is generally recognized both by employers and by organized labor, the fact that it is equally true within the same trade or occupation is totally obscured by false prejudices. Consider a case of two firemen in the same boiler-room, handling the same load and using the same coal. It is frequently to be found that one man can produce 1000 pounds of steam with say 100 pounds of coal, while another burns 150 pounds to produce the same quality and quantity of steam. Now, if the second fireman gets a standard wage of say four dollars per day which represents the value of his work, the value of the work of the first fireman is much higher, as his superior skill, knowledge, attentiveness and general intelligence is instrumental in saving a large quantity of fuel.

What then is the difference in the values of the labor-power (and actual work) of the two of our firemen? Working at their respective efficiencies the second fireman burns sixty dollars worth of

coal while the first one, for the same purpose uses only forty dollars worth. *His labor-power therefore is worth twenty dollars more than that of his fellow firemen.*

The inequality of the value of their work is thus plainly exposed. Similar examples may be multiplied without end in any trade or occupation. The question now to consider is whether this inequality of labor values must fetch different labor-price (wages) and if so, whether this inequality of earnings endangers social equality and democratic principle.

The answer to the first part of the question has been already given, namely, that different degrees of skill must fetch different wages as their values and cost of production are necessarily different. The second part of the question asked by pseudo-democrats has been similarly answered in a most unequivocal manner: The right of the producers is proportional to the amount of work they furnish; *the equality consists in that the labor is measured by an equal standard.*

In our example of two firemen the amount of work they furnish may not be correctly understood at the first sight. It appears as if the more wasteful fellow furnished more work by shoveling 50 per cent more coal into his furnace. The fact however is that by doing so he destroys the results of work of miners that dug out his coal, of railroad men that brought it in, of mechanics that built and repaired machinery used in mining and transportation and scores of other men and women whose work was directly and indirectly needed to get to the boiler-room the coal which he, the less skillful fireman, sent up the chimney. While the more efficient man indeed furnished the country with the amount of work done not only by himself but also by all those who were engaged to produce the coal he had skillfully conserved.

Various methods of compensating extra efforts, additional amount of work of superior efficiency or quality of work have been suggested and tried for some time past. These methods were variously called "rewarding individual efforts" "differential piece rate," "premium plans" and a large variety of "bonus" methods. At this point the author desires to vigorously object to all these names as all of them imply a false meaning of a gift or gratitude; of something that is *given* when actually it is *earned.*

Another fundamental misconception of all these premium plans was that the amount of additional payment depended on an arbitrary decision of the employer as to what part of additional labor value he retains for himself and how big a remainder he will distribute

among the wage earners. The third common shortcoming of most of these schemes is that "extra" reward is offered as a stimulus to induce accomplishment rather than as reward for learning.

The first fallacy shifting the problem from the economic ground into moral abstraction makes it uncertain, subject to the good will and mood of employer, and unreliable from the workman's standpoint. Indeed in some large industrial establishments bonuses and premiums were discontinued with change of management. The second point frequently discredits the best intentions in the eyes of workmen as it is suspected that the added value of labor is out of proportion larger than the reward offered.

The last fallacy, that of offering premium as a bait, is the most dangerous one from the labor view as it is capable, unless safeguards are introduced, of tempting some to overwork themselves in an attempt to reap large premiums; in any event men left to themselves to discover the best method of work cannot do more than "work harder." It is the function of the administration to both discover better methods and provide training and facilities for practicing same. More detailed analysis of these shortcomings of the various premium plans have been published by the author [101] and need not be again repeated.

Profit sharing, co-partnership and similar schemes should not be confused with premiums and bonuses. Profit sharing has nothing in common with wages, indeed it is a plan to reduce standard wages by making earnings dependent upon the success of the business. Yet business transactions are obviously independent of the workman's skill and methods of production. Profit that is to be shared is made principally on sales and the higher the goods are sold on the market the higher is the rate of profit. *Thus profit sharing plans try to combine high prices with low wages.* When finally the dividend is declared and the employees get their share, this share is obviously smaller than the total increase of profits and so the workmen lose "coming and going"; by supporting increased profits he increases the cost of living, while counting on a share of these profits he accepts lower wages.

As Lincoln said it is not possible to fool all the people all the time; in fact these profit sharing schemes, according to reports of the United States Government, have an average life of seldom over five years. The advocates of such plans generally admit that they do not work very well with workmen while profit sharing is more successful with salesmen and officials. This strongly supports the author's statement that profit sharing depends on sales-tricks, and not

on cheap and efficient production. Again, it is a known practice to sell certain goods at times below the cost to attract buyers to highly profitable lines. The aim of profit sharing and that of efficient production have nothing in common; indeed *profit sharing is a conspiracy to make people tolerate and pay for waste* incurred in production and made up in sales.

The modified bonus plan practiced by the author for many years with entire satisfaction is characterised by freedom from the above handicaps and deficiencies. The two-rate wage is based on following fundamental principles:

1 It provides means and facilities for securing and developing additional skill

2 It offers extra compensation for exercising the acquired skill, over and above guaranteed wage

3 The amount of "bonus" is a definite part of the additional value of the work done

4 It eliminates arbitrary adjustments as it is based on measurement of quality of work the man performs, adjusted for conditions beyond his control

5 It prevents overwork inasmuch as quality, not quantity of work is the measure of value of work

6 It secures equality (both of opportunity and of compensation for skill) as it is based and measured by an equal standard.

Practical application of this modified bonus plan, which is actually a two-rate wage, demands the fulfillment of certain prerequisites as to the mode of management, or rather administration of the plant. In order to provide means for securing superior skill, the first step is a thorough, minute and complete study of:

1 Possibilities that could be realized with the existing plant layout and equipment

2 Best fitted fuel and supplies for equipment and service demand

3 Best method of controlling processes

4 Adjustment of hours of work

5 Securing safe and sanitary conditions

6 Division and definition of personnel's functions

7 Adequate, continuous, accurate and graphic recording of performances and conditions.

When these studies are completed (and they cannot be carried out without suitable instruments and expert direction), actual training and instruction may be carried out. In this stage of the work those employees who assisted in discovery and standardization of best conditions and methods become leaders and instructors, their chief work consists in helping less skilled and newcomers to acquire necessary knowledge and expertness.

The science of management has been sometimes defined as the transfer of skill from men to machines thus robbing man of his most valuable possession and at the same time making his work auotmatic and monotonous. Nothing is farther from the truth. Whenever science is applied to the problems of production, whatever skill is at the command of specialists is *transferred to men,* in order to enable them to use the machinery more intelligently. The exercise of this intelligence and skill, resulting in greater operating economy fetches additional compensation, that is, secondary wages over and above primary rate of wages which is merely an accepted cost of living for a given trade or occupation.

Thus if it has been determined that an extra skilled fireman can increase evaporative efficiency say from an average of 60 to 70 per cent, which in a given plant represents a saving per man per shift of say two dollars, a definite agreement may be entered that for instance half of the saving be the share of the owners as their reimbursements for expenses incurred in providing facilities, cost of experiments and compensation for educational work, while the other dollar will go to firemen who, by learning better way and following it, performed more economical work.

In each case, or in each occupation, the conditions are so analyzed that the quality of the man's work is independent of the preceding operation or of mistakes of others, at least as far as the present state of art permits; in cases of doubt or if quality of work is spoiled by others or by uncontrollable condition or by mistake of management, the secondary rate of wages (bonus) is paid, the management thus accepting responsibility for lack of knowledge or control.

In the case of firemen, for example, neither cost of steam nor quality of fuel, gas and ash nor any other isolated or complex criterion would form a correct basis for judging the quality of their work. Efficiency of generation of steam, equated for quality of fuel, quality of steam and temperature of water does represent however the basis upon which the measurement of the quality of work can be made accurately as involving none of the elements over which firemen has no control. Exception may be pointed out

as to physical conditions of furnaces and boilers. This is generally taken care of by provisions for best maintenance; if this is neglected, a bonus is paid to firemen irrespective of results.

Under such condition the "speeding up" and dangers of overwork are unthinkable. Quality being the criterion, results are in the direction of reduction of physical fatigue. Indeed in most of the cases a great reduction of working hours increases the efficiency of work to such an exetnt as to make it very desirable from the viewpoint of the employer to reduce the number of hours. Many examples are known and reported that shortening of working day increased productivity and cheapened the product. In power-plant work reduction of hours from 12 to 8 *alone* produced a fuel economy nearly twice as great as the pay-roll of an additional shift of firemen (getting per 8 hours as much as per 12 hours before); and the author has some data indicating that four six-hour shifts will further improve operating economy.

From the preceding brief outline it is already clear that efficiency or skill of performance adopted as a basis for secondary wage payment furnished a basis of equality in measurement. Physical inequality of men have hardly anything to do as no unusual or extra strain is required. Wherever such conditions prevail, as in yard labor, the judicial adjustment of jobs to men solves the problem. Furthermore, the training and instruction provided, offers means by which anyone can attain a desired degree of skill and secure results fetching secondary rate of wages. Again, as in the case of firemen, if certain efficiency is accepted as an evidence of skillful operation, the inability of boilers to produce much greater efficiency are so rigid and well established that there is no sense in apportioning the secondary wage rate to a degree of efficiency, while in other occupations with wider limits of possibilities it can be accurately measured and rate advanced in proportion to the degree of expertness in securing larger economies.

An added advantage of this plan could be mentioned here, but the author prefers to use the language of Viscount Haldane, a man prominent in British industrial life and active with problems of reconstruction. Said he referring to the plan of uniting hand and brain work: "Monotony will at least be diminished when men feel that they have always to be thinking when they act, and that the occupation of the workmen depends on knowledge and skill, and belongs to what is truly a profession. It will require education and training to bring this about, but if it can be done, even partially, it will give more freedom of the spirit and it will give something more

besides. It will afford an opening for exceptional talent, and for its development to the man who possesses it. For the factory and the mine will tend to become places where there is a graduation of direction, dependent on capacity for directing." To this the author would add that in a number of instances, where our plan is working, it works actually in this direction, and Haldane's *"if* it can be done" is answered by facts.

Concluding his report on the working of my method for several years at the Penn Central Light and Power Company, the superintendent of plants said to the convention: "Not only have the results of the introduction of the new boiler-room practice been most gratifying from the standpoint of reduction of expenses to the company and improvement in the conditions affecting the workman and *his* compensation but it has also increased the mutual respect between management and workmen and has developed the *esprit de corps* which is so beneficial to both." [102]

Again, this method of meeting the labor problem was emphasized by the chief engineer of Strathmore Paper Company when he said to the Technical Association of Paper and Pulp Industry:[103] "The human factor in this whole work is of paramount importance. With the present scarcity of labor, high rate of wages paid in other industries, and numerous temptations to quit and try luck somewhere else, we have felt that no effort should be spared to make our employment as attractive as possible. We therefore started our reorganization by building service room for boiler-room employees, with shower bath, lavatories and lockers. We provided restful seats in the boiler room, an ample supply of running water for drinking, improved ventilation, better designed tools, wheelbarrows rebuilt to carry heavier loads with less effort, and other minor improvements and conveniences to make the work less arduous and more pleasant. The results have fully justified the expenditures."

Last but not least this work of increasing the skill of the employees and compensating them for the exercise of it accordingly, brings about the reduction of the working hours. Exercise of higher skill requires more attention and, since physical endurance of men is greater than mental or nervous, long hours and high economy are incompatible. The twelve-hour shifts are always replaced by eight-hours, while six-hour shifts are still more promising. In every case of course, men get the same per diem standard wage.

Now the last question before us is that of effect of this two-rate wages on the cost of living. It has universally been observed that whenever wages are increased the cost of living increases also

and the net gain of wage earners is short-lived and frequently fictitious. This fact is inevitable inasmuch as wages, constituting part of the cost of product, are included in selling price. The larger the wages, the larger is the addition to the price of product, but since one branch of industry depends and influences all others, not only the price of one product rises but of nearly all of them, which, in turn, leads to demands for wages increase in other industries. Moreover, countless examples could be cited when small advance in wages was used as excuse for large increase of selling price.

The two-rate wages cannot produce this economic effect; indeed quite the contrary, that is, the drop of prices correspond to high secondary rate. The reason is obvious. The amount of secondary rate of wages depends upon exercise of additional skill. Additional skill improves method, reduces waste, minimizes interruptions, increases productivity, etc., and hence reduces the amount of materials worked into product and decreases the overhead expenses, charged to it. *Thus the amount paid as secondary rate wages is already deducted from the production cost.* Moreover, so long as the employers themselves retain a portion of this value from more skillful operation, their profit is safeguarded, if not increased, even when the product is sold at a lower price.

The inevitable consequence of this situation is that earning more, the employees can buy more thus stimulating industries and providing more employment without running the risk of creating business depression. Many years ago, the late Dr. R. H. Thurston made a prophetic statement: "Our present common wage system must inevitably be improved upon in the coming decade if we are to avoid very grave disturbances in our social system. Clouds have been gathering for a half century, and they are growing more numerous and darker continuously. A storm will surely come if a pleasanter atmosphere is not introduced as the result of the efforts of wise and thoughtful men in the immediate future." The employers were slow to take notice and readjust the wages and relations and so to-day the country has to pay for their blind obstinacy of not following the teaching word of an engineer.

Chapter VIII

MASTERING PROCESSES

ANY wilful act must have a preconceived aim. Until very recently business had as its sole aim the securing of profit through marketing a commodity and the satisfaction of the needs of the community, the nation and humanity was not the aim but merely the means whereby the profit could be obtained by supplying these necessities. Hence, the cost of production was a matter of subordinate importance; the main issue was whether the difference between the cost of the product and its market price was great enough. Working along the line of the least resistance, more attention was paid to the increase of this difference by enhancing prices and stabilizing markets, than by a reduction of manufacturing expenses.

The war brought forward a new aspect—the supremacy of the needs of the community to those of an individual, and production for the common good became a keynote of the industrial readjustment. A task of such magnitude caused the shifting of the center of gravity in the problem of industrial management—that is, the reduction of industrial wastes became the predominating supermost task. As long as this is done with corresponding decrease of production cost it is obviously to the mutual benefit of private enterprise and the welfare of the country. Whenever it is not so, or the task appears to be a difficult or hazardous one, the state must assume the risk of operating the socially necessary industries.

With the present speculations on fuel and corresponding increase in the cost of power, with the existing possibility of curtailing production due to lack of fuel, not to mention the coexisting danger to the health and well-being of the people, the problem of wise mastering appears in all its gravity and assumes the importance of an international issue.

The customary hit-and-miss attempts at fuel conservation, labor conservation, etc., that came into favor during the war had at that time the excuse of necessary "speed to meet the contingency without diving into refinements." But "autocratic

efficiency" must give way to a "democratic coöperation" in order to accomplish larger and lasting results.

While a measure of improvement in our national game of destruction of fuel was announced by the Fuel Administration, the margin of preventable losses still remains extravagantly large, and we hardly can be satisfied with the old haphazard methods in the face of our task of reconstruction. The real mastery of processes begins with a study of the laws of the phenomena which we wish to control. An engineer not equipped with a thorough knowledge of philosophic methods and not trained along the lines of logical scientific analysis will fail to accomplish much in this branch of the profession. It can truly be said that we know but little of the nature of the forces with which an engineer must deal; electricity is not as yet susceptible to any definition; heat may be explained by a half dozen different theories, hypothesis of phlogiston, atomistic theories, etc., are nothing more than exhibitions of our mental inability to understand the nature of things; and our efforts to represent the so-called "laws" of nature in mathematical form of equation, curves and formulae are nothing more than a convenient method of memorizing certain similarities observed from repeated phenomena. However, a frank admission of "ignorabimus" in respect to certain subjects does not diminish in the slightest the value of the present state of science; still less may it discourage the earnest effort to strive for further discoveries and better understanding of phenomena with which we have to deal.

The year 1620, when Francis Bacon (Baron Verulam, Viscount St. Albans) published his epoch making work, entitled Novum Organum, may justly be regarded as the date of the birth of the modern or positive science. Rigorous observation and careful experiment, the accumulation of facts and systematic analysis of separate instances before probable truth could be affirmed—such is the general conception of Bacon's achievement. But, like all epoch-making works, Novum Organum gave expression to ideas which were already in the air. The time was ripe to wipe off the decaying scholasticism and authority of churches and traditions were discarded. Any progress, especially in scientific discoveries, is made mainly, if not solely, by the employment of hypothesis, and for that Bacon's rules of induction cannot be applied. Yet, the framing of an hypothesis is no mere guess work. It requires a preliminary critical induction and subsequent experimental comparison, verification, and proof, the canons for which

may be laid down with precision. This task was accomplished by Bacon in his philosophy of induction, giving prominence to such powerful logical instruments as exclusion or elimination.

The application of the principles of scientific analysis, as should be expected, was first made to the research work conducted in laboratories, libraries, universities, and engineering bureaus, and it was only very recently, through the indefatigable efforts of F. W. Taylor and H. L. Gantt that the principles of scientific researches were brought into the shop and adopted to explode and wipe out the fallacies of traditions, opinions, and habits that reigned supreme in our everyday toil. During the last score of years much has been said and written on the subject of scientific management and not infrequently the question was asked "why it is termed scientific?" Indeed the question was asked frequently and persistently and the majority of answers were so evasive that some writers began to use quotation marks for scientific management as if they wanted to repudiate all responsibility for the use of this term. It seems therefore doubly profitable to quote here from Bacon's Novum Organum a few paragraphs, as upon these principles, as well as those almost simultaneously laid out by Descartes and his Cartesian school, all modern or positive sciences were based and developed. Bacon's critique of unscientific method and then his constructive canon of scientific investigation, truly should be read at least once a year by anyone who does not care to get into a rut.

Unscientific Method

"81. The majority so far from proposing to themselves the augmentations of the mass of arts and sciences, make no other use of an inquiry into the mass already before them, than is afforded by the conversion of it to some use. . . .

"82. It is sufficient to astonish any reflecting mind, that nobody should have cared or wished to open and complete a way for the understanding . . . and regular, well-conducted experiment; but that everything has been abandoned either to the mists of tradidition, the whirl and confusion of argument, or the waves and mazes of chance and desultory, ill combined experiment.

"When anyone prepares himself for discovery, he first inquires and obtains a full account of all that has been said on the subject by others, then adds his own reflections, and stirs up and, as it were, invokes his own spirit, after much mental labor,

to disclose its oracles. All which is a method without foundation, and merely turns of opinions." (Novum Organum, p. 339.)

"84. With regard to authority, it is the greatest weakness to attribute infinite credit to particular authors, and to refuse his own prerogative to time. . . . For truth is rightly named the daughter of time, not of authority. It is not wonderful, therefore, if the bonds of antiquity, authority, and unanimity, have so enchained the power of man, that he is unable (as if bewitched) to become familiar with things themselves. (Ibid. p. 341.)

Scientific Method

"100. We must not only search for, and procure a greater number of experiments, but also introduce a completely different method, order, and progress of continuing and promoting experience. For vague and arbitrary experience is (as we have observed), mere groping in the dark, and rather astonishes than instructs. But when experience shall proceed regularly and uninterruptedly by a determined rule, we may entertain better hopes of the sciences." (Ibid, p. 351.)

"101. . . . no experiments have been committed to paper. We cannot, however, approve of any mode of discovery without writing, and when that comes into more general use, we may have further hopes.

"103. Our road is not a long plain, but rises and falls, ascending to axioms and descending to effects."

"105. In forming axioms we must invent a different form of induction from that hitherto in use; . . . a really useful induction for the discovery and demonstration of the arts and sciences, should separate nature by proper rejections and exclusions, and then conclude for the affirmative after collecting a sufficient number of negatives."

"108. We may, therefore, hope for further, better, and more frequent results from man's reason, industry, method, and application, than from chance and mere animal instinct, and the like, which have hitherto been the sources of invention."

"113. For men then only begin to know their own power, when each performs a separate part, instead of undertaking in crowds the same work."

"121. . . . (our method) will appear to the vulgar, or even any mind accustomed to the present state of things, fantastically and uselessly refined. Hence, we . . . must again repeat, that

we look for experiments that shall afford light rather than profit."

Since this has been written, the facts have proven that the statement of Bacon regarding experiments affording "light rather than profit" is altogether too modest, because this very "fantastically and uselessly refined" experimental, or scientific method, when applied to industry (particularly power industry), affords indeed a great deal of material profit.

The application of these methods of scientific analysis to chemistry, technology and all forms of engineering brought about results the significance of which we may grasp only if we compare the state of science and mode of living of to-day with these of the seventeenth century. As applied to the mastery of our technical processes, this scientific method of analysis or research begins with the study of elements and proceeds through experimental observation of their interrelations and influence one upon the other to a synthesis. Insufficiently clear understanding of these principles often creates a confusion of *means* with *methods,* that is, a confusion of forms and implements with the method. Quoting from the author's second lecture given at the Sheffield Scientific School, Yale University in 1915: "It is not the result that we seek, but the method. Under the proper method the best result will be obtained unavoidably."

To accomplish this task we evidently must have the aim, the plan, and the mechanism whereby the aim can be attained by following the plan. Yet in putting this scheme into practice, these three elements become so closely interrelated that a superficial observer may fall into a trap and accept mechanism for the plan and its working for an aim. Obviously, great confusion will arise in such a case when incidental and auxiliary facts are regarded as a basic and essential. Such a "system" is bound to degenerate into irksome and useless ballast. Thus tests, records, etc., while invaluable as a means for discovering the truth and the best ways of accomplishing certain work are useless if made out merely to fatten the files, and are decidedly harmful if carried out without a clear understanding of the purpose they are ultimately to serve.

In many a power plant of to-day, especially of a large size, it is common to find not only generating equipment of high potential efficiency but also an array of up-to-date instruments, measuring and analyzing devices and an assortment of printed forms, logs, card-indexed files, etc. In other words, the means available seem to be as nearly perfect as may be obtained, yet the re-

sults secured are far from perfect, for faith is pinned to the forms and mechanism and not to the principles and methods of using them.

The designers and builders of power-plant equipment, mak-

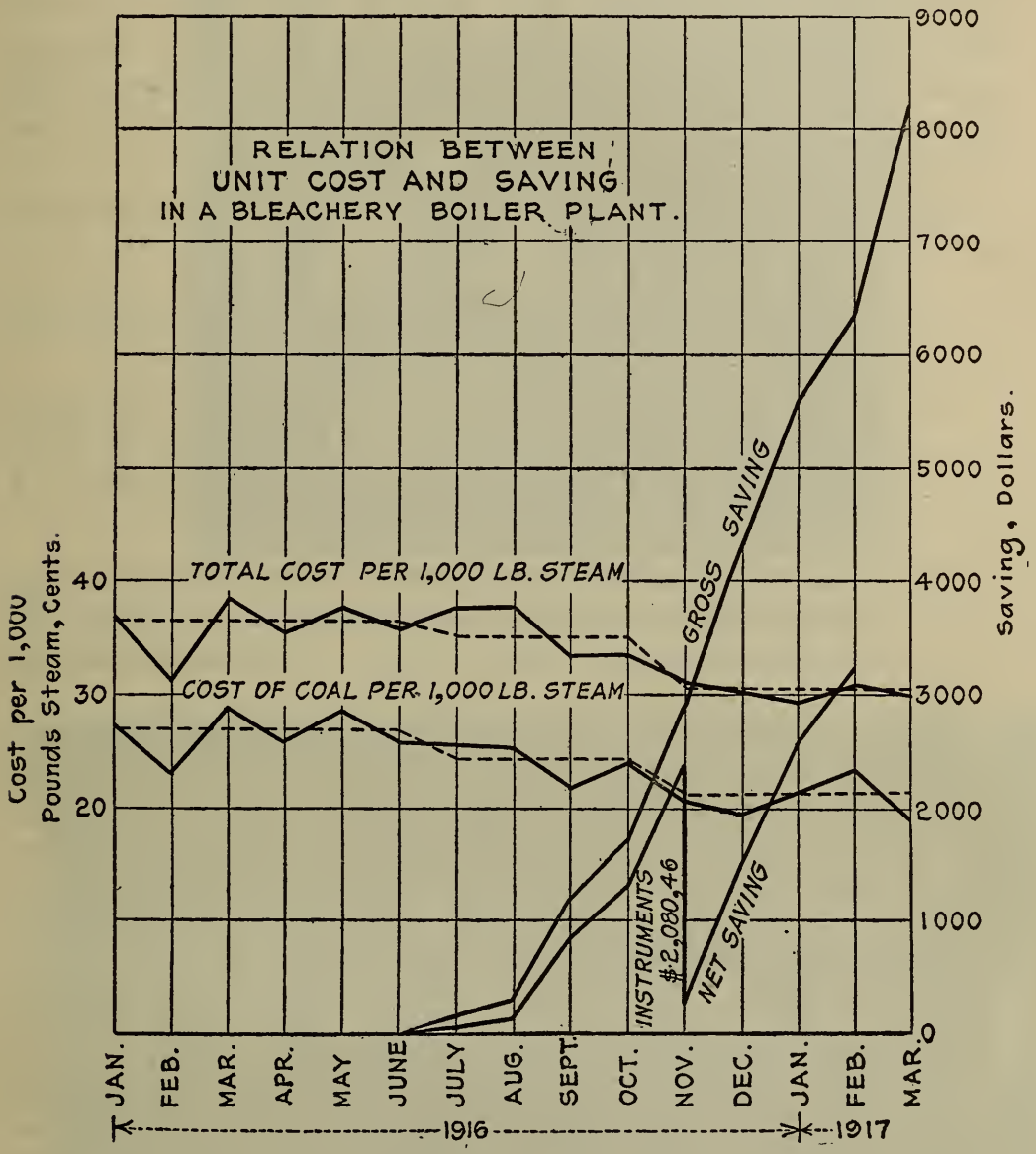


FIG. 58.—NET SAVING DUE TO THE USE OF BOILER ROOM INSTRUMENTS

The characteristic actual case from the files of the writer indicates that the complete installation of the boiler room instruments as shown on Fig. 59, paid for itself within six months. Report on the case is reproduced in the text.

ing a thorough use of the present scientific methods, apparently left nothing for the operating engineer and the manager to do but to secure the maximum efficiency inherent in the machinery they have calculated, designed and built. Weight, speed, frequency, voltage, capacity, steam consumption, etc., of a generator are

known before the drawings are sent to the shops and after it is built its characteristics and efficiency are the same as were predetermined beforehand. Yet the same turbo-generators attended by different men would show different degrees of efficiency depending on their judgment and skill; again the same firemen using same boilers and the same fuel would produce different results under different modes of management. *The problem is thus to predetermine the desired result of actual operation and to find the method of actually securing it.*

The first part of the task evidently involves finding answers to three separate questions:

1 What is the maximum inherent efficiency of each individual and variously combined units of equipment?

2 What is the possible maximum efficiency of the plant (consistent with the nature of the service and safety of operation) that results in the minimum expenditure of materials, efforts and money?

3 How can this ultimate practical efficiency, inherent in any given plant, be secured (consistent with the most benefit to the community) under variable conditions of service?

In the process of power production we have to reckon however, not merely with thermodynamic transformation of energy, but with human and social forces as well.[104] Paraphrasing my oft-repeated statement that *it is not the perfection of equipment but the mode of its use that causes the success or failure of operation,* the Engineering Bulletin No. 2, prepared by the United States Fuel Administration, admits that "a good plant poorly operated will show low efficiency, while a poor plant skillfully operated will sometimes show a relatively high efficiency." Indeed it becomes almost a trait to repeat that "the performance demonstrated during the test is seldom attained in practice" or that "conditions change from day to day, from hour to hour, even from moment to moment. These changes must be interpreted, and the degree of intelligence with which they are interpreted marks the degree of success which will be realized in fuel saving." *

Mr. Lazarovich-Hrebelianovich described[105] a glaring case of this rise and fall of efficiency in a public utility power plant. A

* See discussions of author's paper "Standardization of Operating Costs," Transact. A. S. M. E., Vol. 191.

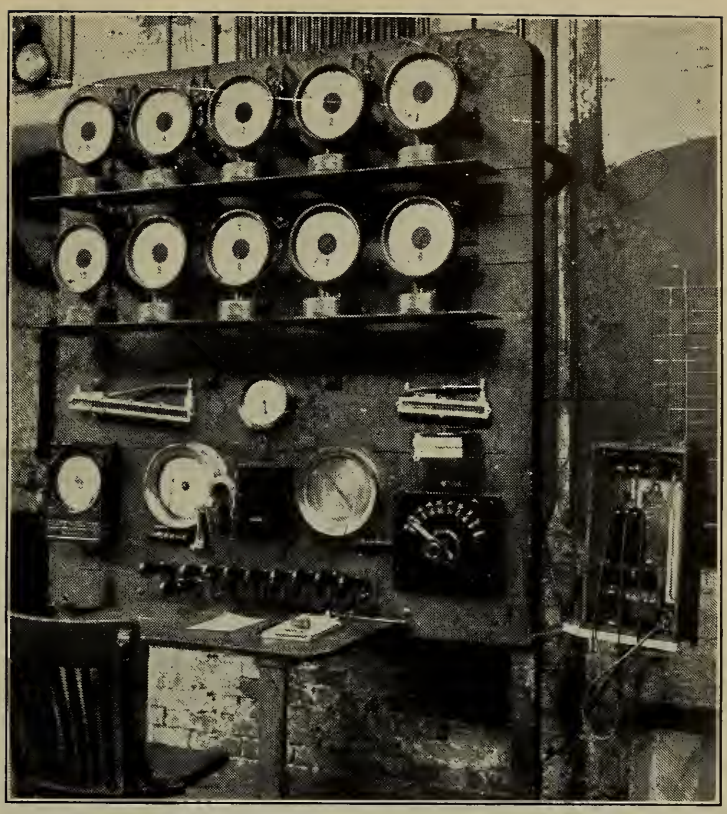


FIG. 59.—BOILER ROOM INSTRUMENT BOARD

The effect of installation and use of this instrument board is shown on the diagram Fig. 58.

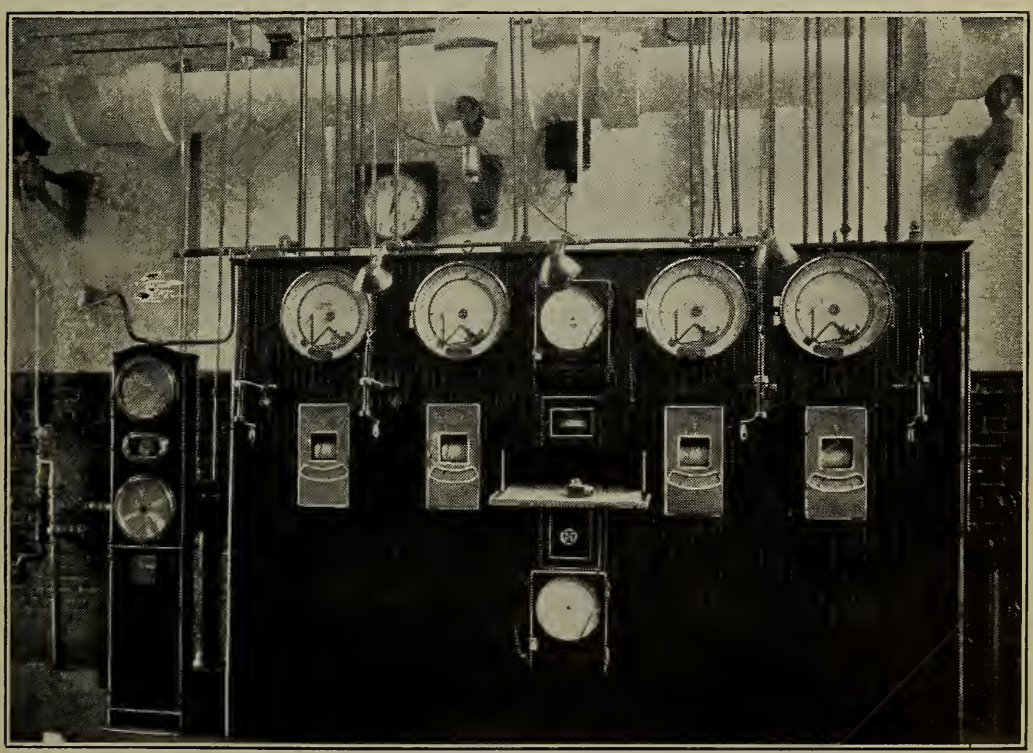


FIG. 60.—INSTRUMENT BOARD IN A BOILER HOUSE

The peculiarity of this board is that every instrument except pyrometer is recording. Note flap desk for log and handles with screw adjustment for proper setting of dampers.

considerable improvement of operating efficiency and economy was attained without any change in generating equipment merely by a thorough study of processes and careful training of employees, while a marked loss in steam-generating efficiency followed the change of personnel. Installation of improved automatic stokers, etc., proved insufficient to restore the former operating efficiency and, while some economy was secured by an installation of larger turbo-generating equipment and increased electrical output, a large amount of fuel was being wasted in addition to greatly increased overhead charges caused by modernized equipment.

Such facts on record offer an argument which should be convincing to anyone that, quite apart from the perfection of equipment, the economy of operation depends on the degree of knowledge which is being exercised in mastering the processes.

Avoidable and Unavoidable Losses

In the preceding chapters we have reviewed the elements that enter into the various complex relations during the process of power production, that is, we have discussed the plant, its equipment and its personnel. Each of these three groups of factors, first studied independently of each other, should now be investigated in their working co-relation and their peculiarities noted and understood. As in any problem involving several variables, certain grouping of them produces different possible limits. The question therefore is now to determine the most favorable combination of variables constituting the plant as a whole. Moreover, as the service the plant is to perform, the load it is to carry and certain other conditions constantly change, we must establish a set of conditions by which we can meet our task under varying circumstances. Naturally, the best possible result will not be the same under every circumstance, but whatever the limit, we must ascertain what is the best result in each case.

A general case presents two distinct phases, the first a determination of limits that are beyond control of the operators and second, a definition of causes and results within the operator's control. Let us take for an illustration a turbo-generator. Its design and construction are such that using steam say of 500 degrees fahrenheit and 180 pounds per square inch pressure its steam consumption will be at a rate of 14 pounds per kilowatt hour when exhausted into a condenser with 28 inches vacuum

and with a total load of say 4,000 kilowatts. Actually there is only a 2,000 kilowatt load to carry and, under this load, the turbine consumes say 19 pounds per kilowatt hour. This loss of 5 pounds per kilowatt hour, or 10,000 pounds of steam per hour, or half a ton of coal per hour plus half the overhead expenses, etc., is obviously beyond the control of the engineers, firemen, etc., for it is caused by lack of demand. So far as this class of employee is concerned, this loss is unavoidable.

Now assume that firemen, maintenance men, and engineers do not attend to their duties in the proper manner; the firemen failed to carry the required steam pressure and to secure high evaporation per pound of coal; the maintenance men neglect superheaters, pumps and stokers; and the engineers overlooked the drop of vacuum, etc. The load being the same, steam consumption per kilowatt hour due to these unfavorable conditions of pressure and superheat and possibly even direct steam leaks increases from 19 pounds to 22 pounds. The loss over and above of that determined as inevitable will be 3 pounds per kilowatt hour or 6,000 pounds per hour, yet the loss in fuel will not be 600 pounds per hour, as it would be if the ratio of evaporation be maintained in the rate of 1 to 10, but still larger. If the evaporation ratio is now 1 to 8, the fuel loss again will not be 750 pounds per hour but:

$$\frac{2000 \times 22}{8} - \frac{2000 \times 19}{10} = 1700 \text{ pounds per hour.}$$

The loss of 1,100 pounds of coal will be due to poor ratio of evaporation and the 600 loss of pounds due to quality of steam and vacuum.

Losses of this character, being due to the method of operation are avoidable so far as the plant force is concerned. From a broader viewpoint of mastering power production, however, both examples illustrate preventable losses, for the loss of the first case, caused by insufficient load for the size of the equipment, may be avoided by securing additional load. If however there is no opportunity to utilize to the full advantage the large unit, this loss might have been avoided if equipment of a more suitable size had originally been installed. This distinction, however, will gain in clearness if we agree to change the terminology and call the losses of first category as *managerial losses* and those of the second group as *operating losses*. The distinction is of great importance from the practical point of view as it helps not only

to allocate the responsibility but, what is more important, to devise the remedy.

The practical task carried out along this line of demarkation is thus divided into two distinct groups of research—first determining what the degree of perfection may be expected from the plant or any unit of it under various requirements of service; second defining what conditions are necessary and sufficient for obtaining this predetermined result.

Obviously, the "degree of operating perfection" permits various interpretations, depending upon the criterion. If our supreme aim were minimum expenditure of money for a unit of output, thermodynamic efficiency, human welfare, safety, etc., must be sacrificed. Again, if ultimate consumption of fuel is the paramount criterion, there might be conflicts with other influential factors. But when the maximum benefit to the community is accepted as the final criterion of the perfection of the processes of power production a definite balance can be found among various conflicting factors.

These considerations bring us face to face with the two new problems: first what is the criterion for judging the perfection of production and second where is the division of responsibility for the attainment of desired results between the operating and directing forces.

Steps in Investigation

Plant owners have for so long been in the habit of putting the blame for low efficiency on engineers, firemen, and workmen that they grew accustomed to summarily keep the employees responsible for unsatisfactory results and exonerate themselves from responsibility by installing equipment represented by salesmen as automatic and efficient. Not less frequently we meet with quite another tendency of talking themselves into belief that the plant is in the hands of "the best engineer in the country," but, having no records nor standards, with which to judge his work, their gain in comfort is greater than in profits.

Both these attitudes, however, are rapidly becoming matters of the past and the more intelligent tendency to find out what the plant is actually doing and what is it capable of doing is gaining ground. As in every case when a new line of studies is undertaken, by men unfamiliar with the problem, a great deal

of confusion is apt to develop. In the days of reciprocating engines the use of indicators was preached and the plant owners developed a fad for demanding indicator diagrams, trying to detect slight maladjustment of valves, but leaving alone poor combustion and evaporation. With turbines coming in vogue steam consumption was expected to follow the builder's water-rate curve and the CO_2 analysis became fashionable. Coal analysis and buying coal on the B. t. u. basis gained at one time a popularity. To be sure measure of gain was secured from all, but the results of these spasmodic studies of isolated factors were naturally so meager that the full extent of possibilities was not even appreciated. Those concerns, that by the virtue of large annual coal consumption or for other reasons, wanted to get more reliable and complete data about their power plants, adopted a policy of periodic testing of their boilers and other equipment. The benefits derived therefrom were similarly of very questionable value and produced in a majority of instances more harm than good, for satisfactory results obtained during such tests were not representative of the average daily practice, yet they often were accepted as proofs that everything was well. The belief that there is no room for improvement, like any other comfortable belief is not easily parted with and many plants, running periodic tests were wasting enormous amounts of fuel and energy. An owner of a large power plant, who ran one boiler out of thirty-six under continuous test throughout a year came one day to a sad realization of futility of such a practice and wrote to me that "if the rest of the boilers were operated as well as our test boiler, we would not have had to use 68,000 tons but only 54,000 tons last year." In other words this policy of sample testing instead of that of continuous records costed him $75,000 each year while the country in five years lost 70,000 tons of coal produced. The ultimate good derived from this lesson, was his adoption of a plan whereby every boiler was receiving the same attention as the test boiler.

Instrument Equipment

The necessity of having measuring devices for the purpose of controlling the processes is gaining recognition but much uncertainty still exists as to the benefits derived therefrom.[106] Obviously enough, mere possession of measuring and indicating instruments is not sufficient to secure an economic operation,

neither reading and recording of the indications could possibly improve the operating efficiency unless the indications are (1) understood, (2) effect on the results interpreted and (3) steps are taken to adjust the operating conditions in accordance with established relations between conditions and effects. Unless the management is prepared to make proper use of the instrument equipment, the investment in such is of doubtful value. This seems to explain the hesitation and doubts with which old-fashioned management meets the requests for such instruments as the plant engineers or salesmen frequently recommend. Again, there are many cases where the investment does not pay for itself because of lack of provisions for its proper use. As a rule, the operating force cannot, without outside or special help, derive full benefit of an instrument for the following reasons:

1 *Lack of time* for preliminary studies of relations between necessary conditions under variable circumstances for securing best results. Operating engineers, plant superintendents and their co-workers are primarily concerned with running the plant, not running the tests.

2 *Lack of training* for very specific and minute observations, investigations and analysis of the data collected during the tests. Special training and long experience needed for this kind of work is usually not required from the members of operating staff, indeed it is often regarded as undesirable—"practical" men being often given preference to scientifically trained ones.

3 *Lack of confidence* is also sometimes offered a great handicap when a large power plant employs "young graduates" to run tests, keep records, etc. These men, if properly guided can be of enormous value for the reason of their training and full opportunity and unlimited time to discredit wrong practice and to devise a better one. Yet, lack of broader experience with operating problems sometimes misleads them as to plan of work, proper perspective of the essential and comparatively unimportant may be lost. Usual outcome of their work is that the findings, however accurate and valuable, are submitted for approval to some one senior in age or position. This person, not having personally developed the practice recommended may (and frequently does) doubt the findings from the standpoint of traditions and habits and not seldom modifies it before putting into use with almost inevitable result that "modification" nullifies its value. If, as sometimes happens, the investigator is given the opportunity to see that his recommendation is lived up to and

new practice is inagurated, he similarily works under a great handicap: men affected are slow to recognize his authority, for he is not directly responsible for the work of the men. The latter, however, fearing a failure if the new practice is adopted, follow it only superficially, clinging as fast as they could to the old established routine. Necessarily, such trials fail to produce full value of advanced practice and the work soon falls into a disrepute.

The engagement of a recognized expert from outside, to direct this study work and pass on thus devised practice, obviates all these fundamental causes of failure of home medicines.

The careful and thoughtful use of instrument equipment (even without payment of two-rate wages or any incentives) invariably produces quick and gratifying results. A report of one power supervisor on the effect of installation of some instruments permitting him, with our help to control more accurately the operating processes is interesting as it is typical of all such cases: " . . . it is evident that in the four months preceding the installation of boiler control board, the savings on fuel, due to various steps taken, averaged $435 per month while, in the four months following the installation of the instruments, the savings computed on the same basis, averaged $1,135. In other words, the increased savings, due solely to the intelligent use of instruments on the boiler control board, was $710 per month or $8,620 on the annual basis, which means that the expenditure of $2,080.46 for instruments of the said board is an investment which in our case yields over 400 per cent profit." Figure 58 shows graphically the savings accomplished over and above the complete amortization of the instrument and installation within the first year, while Figure 59 visualizes the board itself. In passing we should note that the plant in question is a bleachery boiler house consuming between 150 and 200 tons of coal per week.

The next question that comes up in connection with the means for investigating existing operating efficiency and the development of better methods is: What instrument equipment is necessary and sufficient for the purpose? Evidently it is not possible to specify a set of instruments that would meet the requirements of every plant. The character of generating equipment, its lay out, service conditions, specific problems, etc., determines actual selection. In the author's paper before the 1918 spring meeting of the American Society of Mechanical En-

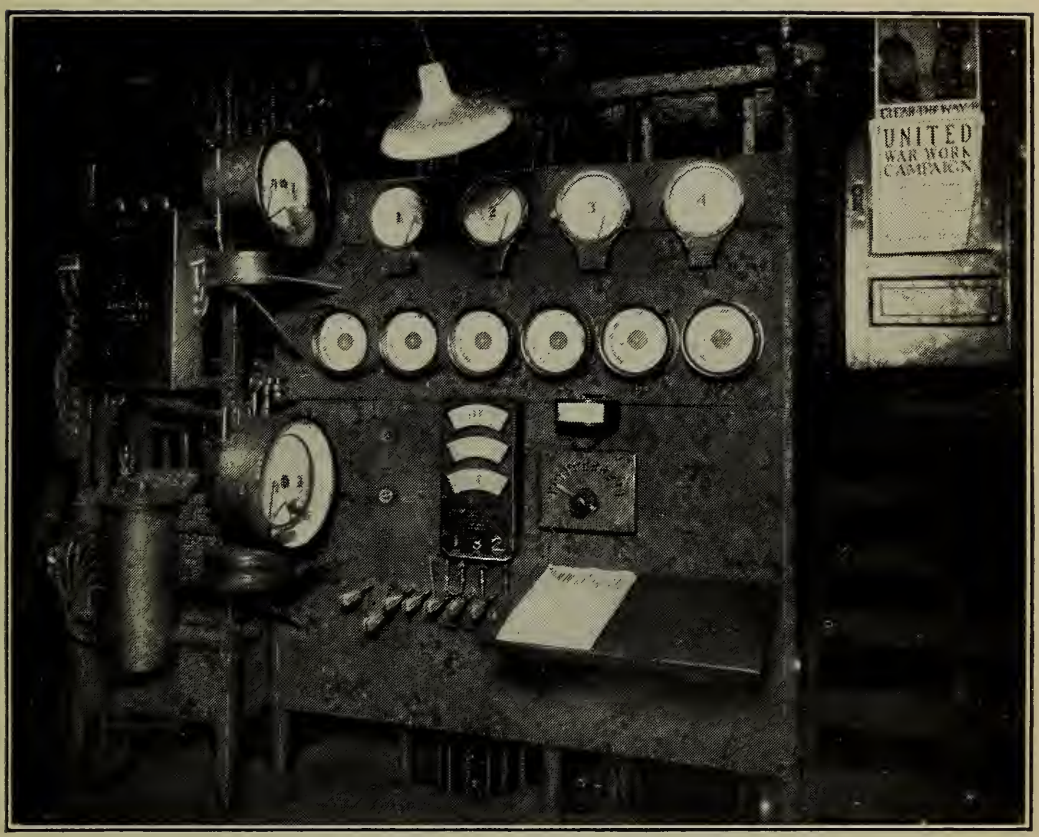


FIG. 61.—BOILER CONTROL BOARD

Note selective connection of any boiler with 3-point draft gauge and flue gas sampler. Each steam main has independent recording flow meter, as well as each boiler, having indicating instrument on board and recording in the office. Each of the three economizers has independent recording thermometer and one recording thermometer for the common feed line from heater. Speed of stokers and speed of draft fans regulated from the board.

gineers we said in discussing this subject: "While the generation of power, and more specifically of steam, is the domain of the scientifically trained engineer, power-plant practice is conspicuous by the lack of accurate measurement of conditions and results."

Unless the results obtained are known, no opinion as to perfection of operation can be sound; furthermore, the practice is necessarily wasteful unless means are available to observe the conditions under which the process is performed. All instrument equipment of the boiler house can therefore be grouped into two classes:

1 Recording the results

2 Showing the conditions.

A plant in which it is not known how many pounds of coal are used per 1,000 pounds of steam, how the load is distributed among the units and throughout the day, etc., wastes fuel by necessity. The knowledge of these data does at least open the eyes of those responsible for its success, and further progress is thereby made possible.

The first group of instruments thus comprises:

Quantity	1	Recording coal scales
	2	Recording steam or water meters
Quality	3	Coal calorimeter and balances
	4	Feedwater thermometer
	5	Steam pressure gauge, and thermometer.

The second group of instruments is intended to direct the processes by controlling conditions:

1 Steam flow indicators

2 Draft gauges

3 Flue gas thermometers

4 Flue gas analyzers.

The substitution of steam flow indicators by coal or oil meters is absurd, as it leaves obscure the output for given input; draft gauges may be substituted by Pitot tubes. Other modifications are sometimes desirable, but the above equipment is necessary and sufficient in general cases.

Any investment in instruments is a pure waste of money, and leads to demoralization unless means are provided for:

1 Training men in their proper use

2 Interesting men in their proper use

3 Providing complete, exact, and continuous records of conditions and results.

Location and arrangement of instruments shall be such as to:

1 Permit simultaneous readings and their comparison for any one unit

2 Permit plain view of units from instrument board and reverse

3 Afford the opportunity to use one instrument for several units

4 Eliminate unnecessary fatigue of observing scattered instruments

5 Assure ease and simplicity for testing and calibration. These requirements are combined in the type of instrument boards devised by the author, typical installations being represented by Figures 60, 61, 62 and 63.

A fallacy of economizing on instrument equipment or ignorant attempts to select only "the most important" ones has only one rival in absurdity—the tendency of installing instruments without giving the employees the opportunity to use them to advantage. Obviously, the operating men seldom have (1) time, (2) opportunity for research work, or (3) inducement to carry out investigations, standardize methods, and set tasks. It should be therefore the duty of the management to render them necessary aid and to assume responsibility for results.

In this connection it may be of interest to give the description of a representative instrument installation in a typical boiler room, employing words of the people using them. This description is that given by chief engineer of a large paper company before the Technical Association of the Pulp and Paper Industry [109] of the boiler control boards which he thus describes were devised by the author to meet their requirements.

"An instrument or control board was installed in each boiler

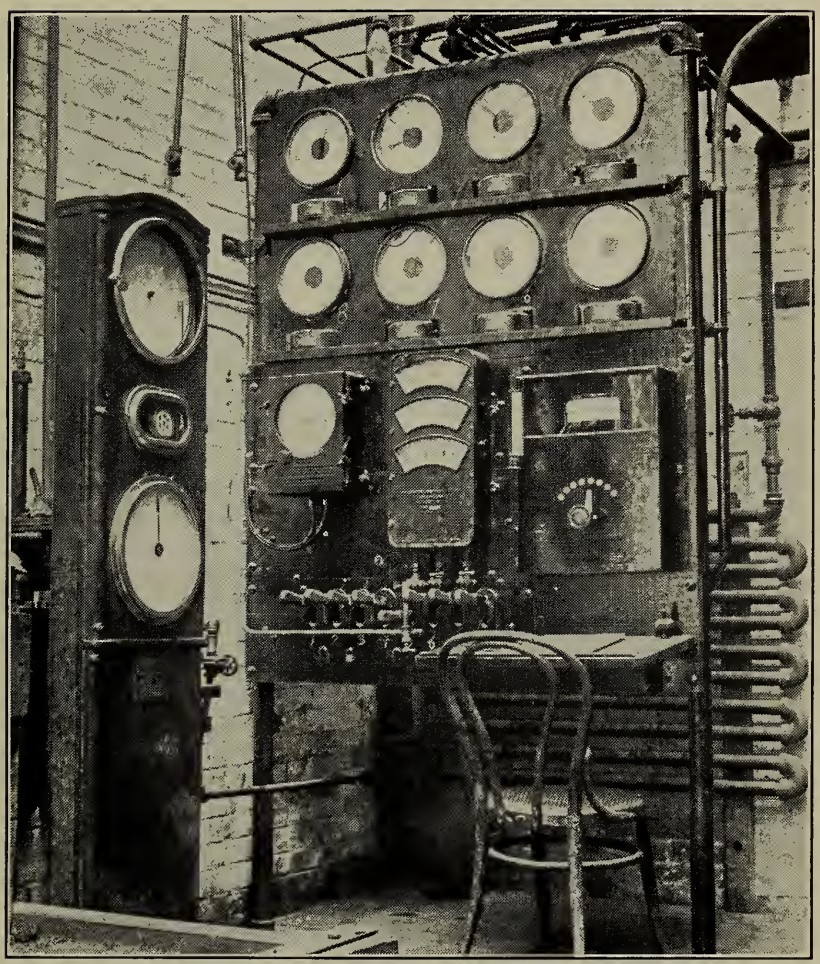


FIG. 62.—INSTRUMENT BOARD IN AN 8-UNIT BOILER ROOM

This board is described in text in details and in general features is similar to one reproduced on photograph Fig. 61. It is installed in a hand-fired plant and not in a stoker-fired plant as preceding illustration.

room in a location readily seen by the firemen. Upon each board were mounted:

(a) Steam flow meters, one piped to each boiler

(b) A combination draft gauge, indicating draft in boiler uptake and furnace, and pressure in ash pit

(c) A recording thermometer with two pens, recording temperature of feedwater entering economizer and boilers, respectively

(d) An electric pyrometer connected to a thermocouple in each uptake, to indicate flue gas temperature.

Adjacent to each board is a Venturi feedwater meter, a gas collector and analyzer, and a portable recording flow meter. The draft gauges are piped to each boiler in such a way that through a system of valves operated by levers, the draft in uptake and furnace and the ash pit pressure can be obtained at once by pressing the lever corresponding to any boiler. Likewise, the temperature of flue gas may be read by making the proper electrical connection for any boiler by turning a hand wheel. The general arrangement of the boards is shown in Figure 62.

The installation of instruments on a boiler control board has several unique features:

(a) Steam flow meters only are individual for each boiler. All other instruments can be selectively connected with any boiler

(b) Indicating instruments are used for the control and adjustment of working conditions of boilers

(c) Recording instruments are employed for registering data necessary for computation of results.

(d) Centralization of instruments reduces first cost—i. e., investment

(e) Centralization of instruments also affords the observer or head fireman the opportunity to compare almost instantly the working of every boiler in the plant." (See Figure 62.)

In the plants where no instruments were previously installed, the progress of their installation offers an exceptional psychologic opportunity for starting the educational work. A valuable

factor in teaching is the interest aroused in the subject and this is invariably the case when a new device makes its first appearance in the plant. Its purpose, mode of use and service-value should be explained before the instrument becomes a permanent fixture; if this moment is lost, the instructor has a doubly hard job, as men seldom have sufficiently keen interest in the old, familiar objects. Moreover, during the period of non-use or even misuse, the instruments not only represent idle investment serving no purpose but create an impression of a senseless fancy on the employee and extravagant refinement on the employer.

Securing the Knowledge

Broadly speaking, there are two ways of acquiring knowledge. The first and most ancient method is based on *belief* in authority, either divine or human; it may be illustrated by the scholasticism of the middle ages and the method of teaching in our public schools. The second, as opposed to the first method, is based on the critical study of phenomena in accordance with the principles of scientific analysis. The entire progress of our life, the applied and pure science, is based on the proper use of this method as a tool. Since the modern or positive science accepts as the criterion of truth the exactness with which the discovered laws (or seeming relations between causes and effects) helps us to foretell the occurrences in time, space and effect, the difference between the applied and pure science is merely that of whether or not we can influence the phenomena at will. We can, for example, foretell the sun eclipse as precisely as putting out the light in our room, but the latter we may cause at will by turning the switch.

Whereas the designers of the power plant equipment may justly be classed as engineers working on a scientific basis, inasmuch as exact character of performance of this equipment is accurately predetermined by them before the drawings are sent to the shops, of few managers could the same be said. To accurately predetermine what results can actually be secured from the operation of a given plant appears to many as an idle quest, while some shrink before the task involving detail studies. Nevertheless wherever these possibilities are determined and the causes producing the most favorable results are clearly established such knowledge alone usually produces results far superior to those obtained before it was definitely known what might be expected from a given plant.

The degree of engineering perfection of power plants is generally reckoned in terms of thermodynamic efficiency. This criterion alone is both inaccurate and insufficient. It is inaccurate inasmuch as the inherent thermodynamic efficiency of the plant, as determined by calculations or by experiment under ideal conditions of a test, is not necessarily attainable in practice. If, however, the expectation is derived from the observation of every-day performance, it is invariably short of possible perfection. These practical standards are usually too low, for fluctuation of operat-

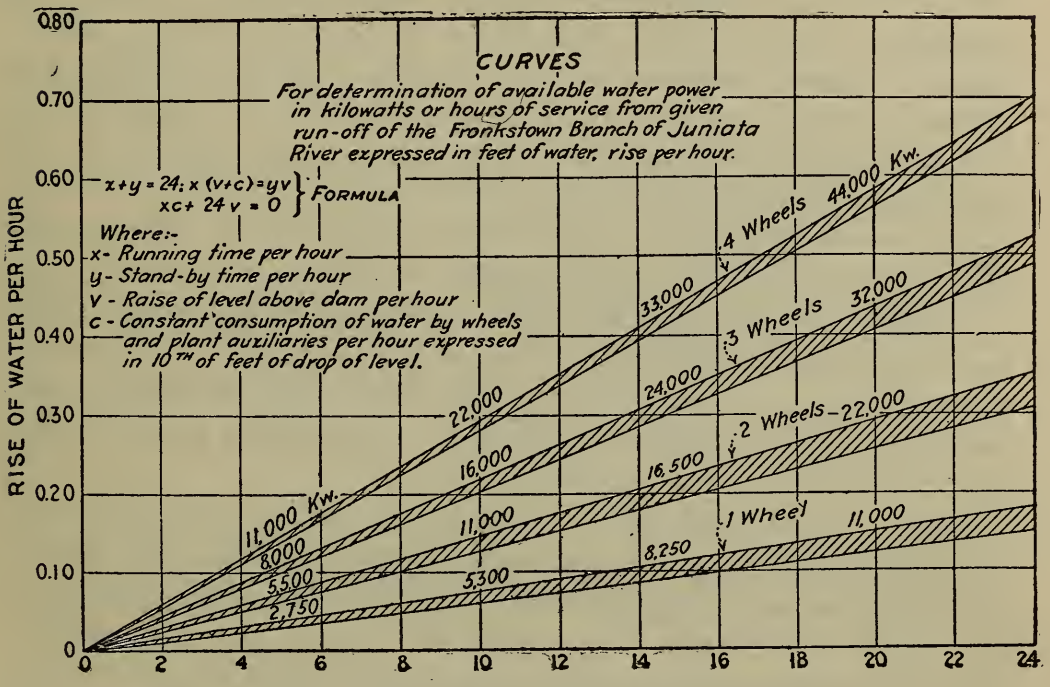


FIG. 63.—INSTRUCTION DIAGRAM

By referring to this diagram the switchboard operator, knowing from log the rise of water above dam per hour, can plan how many water wheels for how many hours and at what load he can run without drawing down the pond, and what portion of the load must be carried by steam turbines.

ing efficiency depends upon the variable human element, mode of operation, etc. On the other hand the thermodynamic criterion alone is insufficient since the conception of thermal efficiency does not include the "time element" which is the chief determining factor in our industrial, commercial and social lives.

Furthermore to accept as a task the maximum thermodynamic efficiency of which the plant or each unit of a plant is capable, would be impractical: firstly, because it is unattainable and a certain gap between actual and ideal wipes out the definite distinction between the best possible and the good results; the

satisfaction by the accomplishment may come too soon, leaving large preventable losses unattended or else the expectations may be placed so high that attainment is impossible under the existing circumstances; this would discourage the earnest efforts of operating force.

Secondly the maximum thermodynamic efficiency is unfit to be a criterion of quality of operation because the securing of high thermal efficiency sometimes involves unwarranted expenses for its attainment or what is worse, may overtax the operators to an unadvisable degree. For instance, it might be possible to secure, under ideal test conditions, in a boiler installation a thermal efficiency of 82 per cent. Yet to maintain this efficiency every day, may not be possible due to frequently or widely fluctuating load, and it would cost many times more to maintain these conditions than it is possible to save on coal. Again, we may find that allowing carefully for the effect of all influential factors we can maintain 74 per cent in every day operation. In this case any task set below 74 per cent would be a deliberate waste while to set it above this mark would be unreasonable as it may be reached only under an exceptional combination of favorable conditions, to duplicate which is beyond the power of the operators.

Mr. D. S. Jacobus, of the Babcock & Wilcox Company, has justly said that "a general impression prevails that test results are one thing and operating results another, and that the operating results necessarily fall considerably below the test results. *Operating results do as a rule fall considerably below the test results, but there is no reason why this should be so in the great majority of cases*" (the italics are the author's).[107]

Indeed it is quite common to read in the reports of careful boiler testers passages like these: " . . . a different fireman was on duty. He fired the boilers and cleaned the fires in a different and apparently more efficient manner than the first fireman . . ."; "the helpers do not realize the importance of coaling quickly and closing doors and it takes them longer to coal than to firemen. . . ." Unfortunately, however, the old-fashioned way of conducting boiler trials and reporting on same totally disregards not only the factors of human skill and interest in the work, but even neglects to record such important physical conditions as the force of draft and velocity of gases through boiler, etc.,[108] thus rendering the entire report utterly without value as it does not point out the way for duplication or perhaps improvement.

The latest code of The American Society of Mechanical Engineers for conducting boiler trials gives similarly unsatisfactory and antiquated rules, utterly disregarding such an important object of *tests as setting task for everyday performance.* Because a locomotive *can* make 100 miles an hour nobody expects a train to get from New York to San Francisco in 30 hours, neither is the 20th Century Limited pulled by an old yard engine. In running boiler, turbine and other power plant tests similar

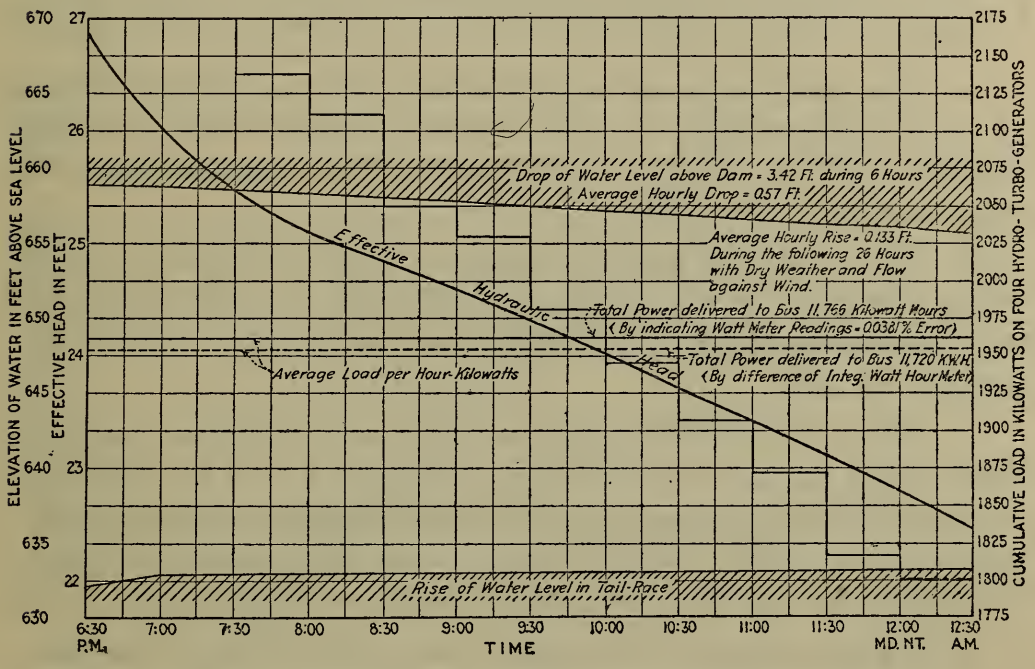


FIG. 64.—LOG OF THE TEST OF HYDROELECTRIC PLANT

Graphically illustrates the relation between the diminished effective hydraulic head (due to drop of water level over the dam and rise of water level in the tail race) and decreased capacity of the generating units. On the basis of such tests the pre-determination of available water power can be made, as exemplified on the diagram, Fig. 63.

inconsistencies are unfortuately only too often made. Knowledge of how fast an engine can run does not tell a passenger when he gets to his station, likewise knowledge of maximum capacity and efficiency of plant equipment does not indicate what operating economy may reasonably be expected from a plant and what should be accepted as standard, all limiting factors being taken into consideration.

From this standpoint all codes and rules for conducting boiler and engine trials are utterly unfit to guide the work of setting standards or tasks. The common shortcoming of all of them

is that they deplorably ignore the main point—for what are the tests made.

The work of testing boilers, etc., is not infrequently conducted by young college graduates or sometimes by the boiler-room force, even in the plants of reputable companies. The data thus obtained are seldom reliable or complete and even if every factor, however insignificant, is measured and recorded, the results are of very limited value except when such a test occasionally discloses a serious leak somewhere so that steps may be taken to remedy these isolated causes of loss. To sum up:

1. The time spent and expenses incurred in conducting tests by untrained persons is a pure waste and sometimes serious harm is done by wrong conclusions derived from such incompetent tests.

2 Tests that are made without keeping complete and continuous records of all conditions should not be run at all, as the conditions cannot be duplicated and results cannot be checked at will.

3 Tests that are not supplemented by time, fatigue- and motion-studies on the men attending the units under the test are of limited value inasmuch as the most important factor is thus overlooked—namely whether under every day service it would be feasible for the men to duplicate the test conditions.

4 No test, unless it is checked and verified by calculation, is of any value; moreover, any test, before it may be accepted as correct, shall be checked several times by repeat-tests of long duration to ascertain that the results once obtained can be duplicated at will.

It is obvious that the task of securing complete and reliable information pertinent to equipment, supplies and men is a most exacting function of the management. It is more than testing of any one process of performance, or time study of any operation. The influence of one or more variable condition on the possible result is extremely intricate but it appears still more complicated when one considers how many variable factors of both psychologic and physical nature must be accounted for in cases as complex as a modern power plant. Yet the difficulties are far from being unsurmountable and the number of sufficient observations is naturally limited by the amplitude of possible changes within its minima and maxima.

Nevertheless the nature of the work of obtaining necessary information, without which the management is but a haphazard undertaking, and the results but a source of either pleasant or unpleasant surprise, is such, that this *work cannot be made a part*

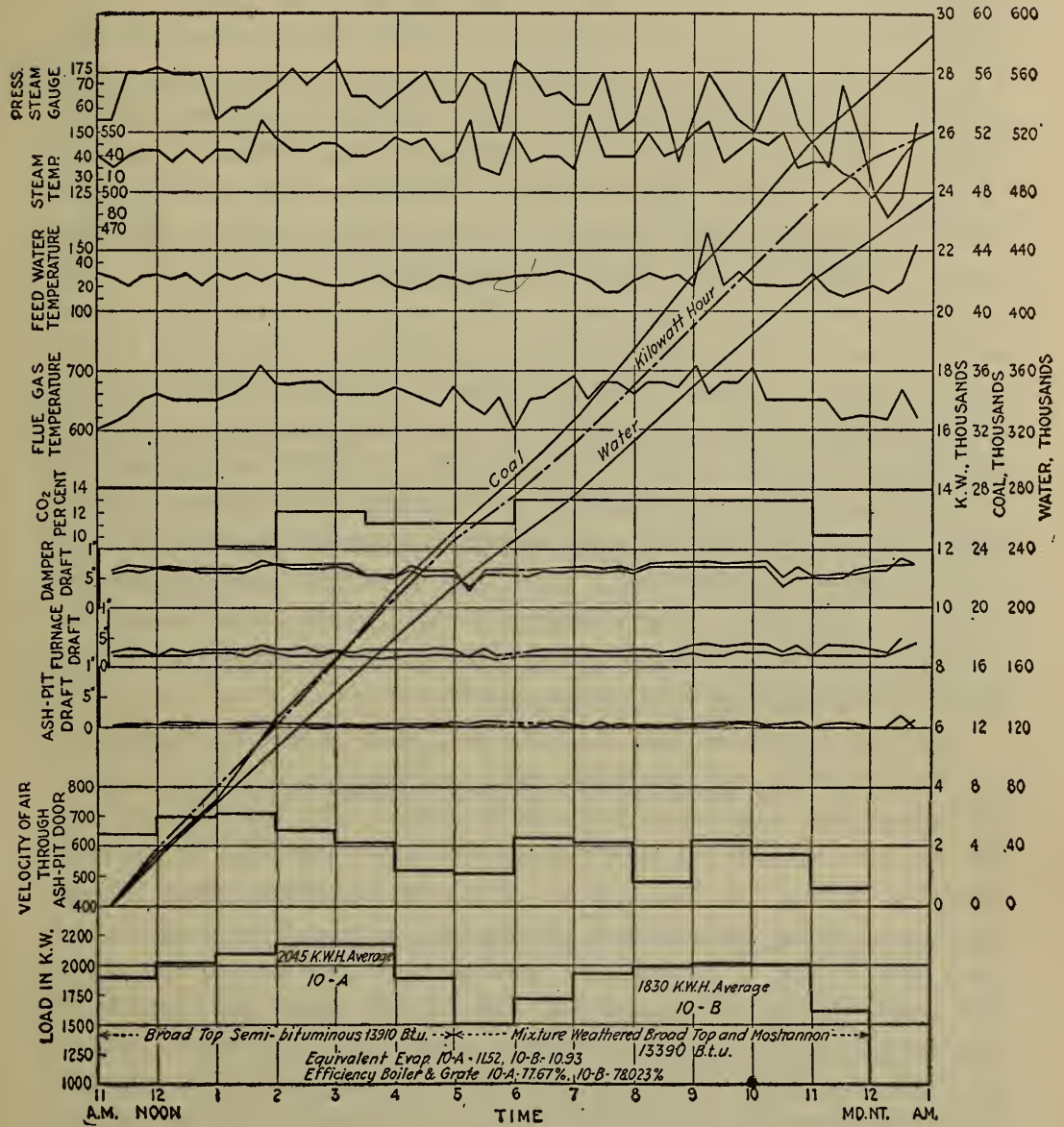


FIG. 64*A*.—LOG OF A TEST

Graphic log of a boiler trial, 2-600 HP hand fired, Edgemoor boilers, with changed grade of coal after six hours' run.

of the duties of some power plant employee. The nature of this research work requires a man of very definite qualifications and one possessing them is too valuable to be engaged in any routine work; again, it is hardly within anyone's ability to do justice to both research and executive work.

This work of securing a knowledge of what each unit of equipment individually and in combination can do and should do under everyday operating condition establishes at once *the task* and the *practice*. There is no need here to go into a detailed discussion of methods of testing and checking the results by calculation first of heat balance, next of cost balance and, finally, if apparently a satisfactory solution is found, by re-studying the problem from the viewpoint of human exertion required and the ultimate effect of newly devised practice on the welfare of society at large. A great deal of such information can be found in various textbooks and professional papers the subject was also touched slightly in the chapter on equipment.

Time and motion studies should receive in power-plant work much more serious attention than heretofore. Engineers of the Taylor School devoted their attention to various manufacturing manipulations, construction work, etc., but utterly overlooked the manual work in the power houses. So far as operations such as shoveling or machine shop work are concerned the power plant hardly present any new problem, but in the boiler room and the high-tension room the field for this sort of studies is most interesting and abundant. Especially interesting researches should be made on the effect of the fatigue of attention on the efficiency of processes.[109]

The old fallacious idea that the best man should be picked out for observations and the task set according to his best accomplishment has long since been discredited. The industry cannot depend on exceptional men; moreover such practice is psychologically wrong as average or even less skilled men, though capable of doing better work are thereby easily disheartened and soon quit trying. Furthermore management receives all the blame for their desire to "speed up" the work, lose the confidence and coöperation of the men and ultimately fall short of not only their unduly high aim but even of a reasonably moderate one, which could have been attained if another view on the matter had been taken. We have found that a hearty coöperation of workmen is invariably secured when men are picked out for studies and experiments from among the average if not from backward workers. Our desire being to help those who do poor work, we meet with quick and willing response from the first pupils. As soon as the new practice is devised and learned the results of their work are so obviously better than the work done by untrained men, who heretofore considered themselves superior to our pupils,

that they have to take notice of it. It generally does not take long until some of those outclassed men come to our instructors with questions, for their trade-pride does not permit them to drag in the tail of the procession. In this manner the knowledge spreads rapidly, amicably and in a perfect spirit of coöperation, while the results depending on all, not on few men doing good work are more satisfactory. Furthermore *a new practice introduced in this fashion becomes respectable* and every newcomer instead of being told that this "system" is "bunk" and only few care to follow it, is at once impressed that doing the work in a certain way is a sign of respectability and good manners. The perpetuation of good practice is therefore assured.

Presentation of Knowledge

When the mechanism and organization for securing the necessary knowledge is developed, the first step toward making this knowledge applicable is the presentation of facts, relations and all other information in a readily available form easily understood at least by the leading men. The manner in which data and information should be presented largely depends upon the nature of the facts and modified as to form according to who and when is to make use of it. Four distinct ways are most commonly used:

1 Diagrams, graphs, charts, tabulations, etc.

2 Slide rules

3 Instruction cards

4 Anunciators, indicating scales, light or sound signals, etc.

Information presented in the graphic form of diagrams and curves is handy for use by engineers, switchboard operators, and like people of some technical training who know how to read curves on the scale. It is conveniently adopted to represent certain final relations omitting intermediary conditions over which these men have no direct control. A fair example of this type of reference is given in Figure 63 which represents the summary of a large number of tests, graphically reported in Figure 64, and giving instantaneous information as to what output may be expected from water wheels during the next twenty-four hours on the basis of the rate at which the water level raises above the dam. Adverse and favorable conditions

of wind, rainfall, etc., are accounted for within the shaded area of diverging lines. Knowing from the log record that the water run off is at a certain rate the operating engineer reading off from the scale on diagram for the corresponding rate can accurately plan how many water wheels should run and for how many hours without lowering the level of the pond below the safe mark and how many hours it will take to build up the pond. Similarly, Figure 65 represents the relation between the steam-turbine load and corresponding permissible steam consumption.

Whenever there is a number of variable factors entering into consideration it is extremely difficult for an operator to exercise proper judgment from a graph like Figure 66 or loosely worded instruction card without going every time into more or less extended calculations. This is neither desirable nor even possible in cases of economical distribution of fluctuating load among several generating units. In such and similar cases carefully prepared slide rules are of great help. Their use is readily taught load despatchers or switch board operators. A simple example is shown in Figure 67 which illustrates a steam consumption calculator devised for determining the most advantageous distribution of total load among three turbogenerators of 2,500 kilowatts, 750 kilowatts and 500 kilowatts each; the water rate of larger unit was shown on the diagram Figure 25.

For men employed in doing repeated manual operations a common form of written instruction card may be advantageously used. It goes without saying that such instruction cards are seldom referred to after the men are trained by an instructor and the proper habit of working formed. The fact that some of the men could not read is by no means a handicap as anyone has to undergo a period of training during which a competent instructor actually demonstrates the motions and their sequence, performing the work according to the instruction card. Samples of such instruction cards for the use of foremen are given in Figures 68 and 69, while Figures 70 and 71 show those prepared for the use of coal passers.

The most convenient and successful form for giving the necessary information to the men working under variable conditions is some kind of indicator or signal either acoustic or optic. In case of hand firing it is sometimes possible to so measure the amount of water fed to the boilers, that every time a certain quantity is "dumped in" a gong rings announcing that a

certain amount of coal must be thrown into the furnaces, thus not only regulating the frequency of firing but also helping to maintain a desired ratio of coal to water. For the purpose of informing firemen as to thickness of fuel bed and strength of draft required for securing maximum efficiency, at any rate of steam-flow, additional marks can easily be placed on the flow-meter dial. In the author's paper on task setting for firemen and maintaining high efficiency in boiler plants,[110] the following description of a similar "fireman's indicator" is given: "The writer arranges on the dial of the steam flow meter an

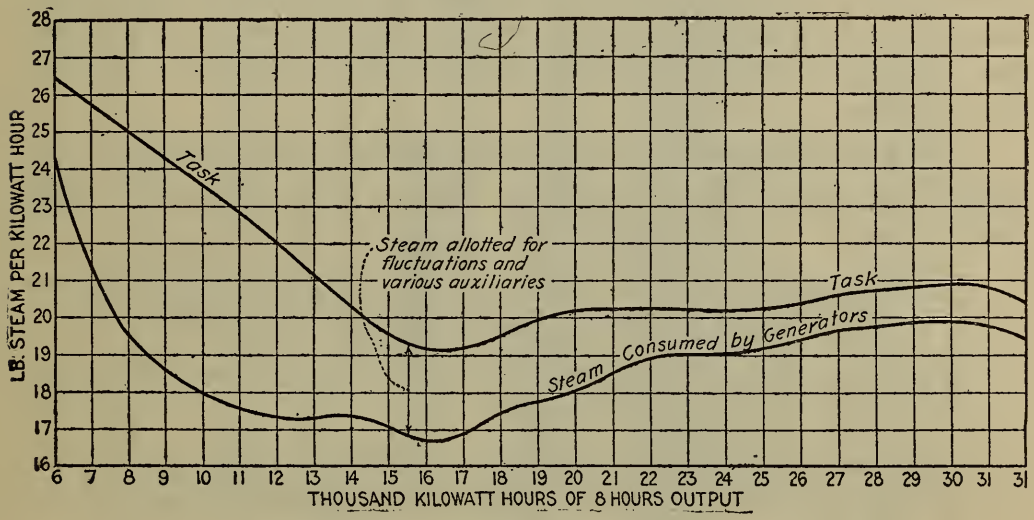


FIG. 65.—INSTRUCTION DIAGRAM

Operating engineer by referring to this diagram can judge how much steam is allotted to an 8-hour watch depending upon the steam electric load carried. The allowance between the curve "steam consumed by generators" and "task" curve is made to take care of ordinary fluctuations in quality of steam and provides leeway for various combinations of auxiliary machinery.

inside dial, as shown on Figure 72, with numbers indicating the required thickness of fuel bed corresponding to the number of pounds of steam drawn from the boiler and a third dial with numbers indicating the draft which is necessary and sufficient to supply the required quantity of air for the combustion at a rate called for by the indicated steam demand. Thus if the pointer, as on the figure, shows that (at any time) steam is flowing from the boiler at a rate of say 14,000 pounds per hour the firemen will know that the figure 4 under the pointer on the middle scale means that a draft of 0.4 inch of water is needed and the location of the pointer on the inner scale between the numbers 6 and 7 calls for a thickness of fires of from 6 to 7 inches."

While such facilities for transmitting the information to the operators are absolutely essential they can not be of any material help unless personal instruction and training is rendered. The best qualified instructor is usually the foreman or an ambitious and intelligent worker—*never an office man.* An instructor must not only be a well-informed man but a skilled one in the art and actually able to do the high-class work from day to day. The surest way to discredit the attempt to teach men a better way is to place it in charge of a man who may be suspected of "bluffing"; such a folly is equaled only by trusting the training to a man though capable but inclined to "bully" his charges.

The following conditions, in the writer's experience, are essential as incentives for men to learn a new mode of doing their work:

1 Management should place itself at the service of men to assist and help them in performing their work

2 Close personal relations between workers and all members of managerial staff

3 Store room, tool room and maintenance department organized to help men to do their work with ease

4 Thorough understanding of mutual aims and establishments of fundamental principles underlying organization and coöperation

5 Accurate record keeping adequately representing condition of work

6 Full confidence on the part of the employees as to correctness, feasibility, and desirability of the new methods

7 Payment of secondary wages for meritorious work

8 Immediate reports as to results accomplished, individualized as far as possible and made known to the men before they return to work the next day

9 Following up of any failure to do good work and explanation to men of causes thereof

10 No authority without full responsibility.

These ten fundamental rules of conducting the plant constitute the administrative policy which, being thoroughly democratic, has proven far superior to any form of centralized management.

The acquisition of superior skill under this regime is as beneficial to society, because of better service with greater economy in natural resources and human power, as it is to individuals

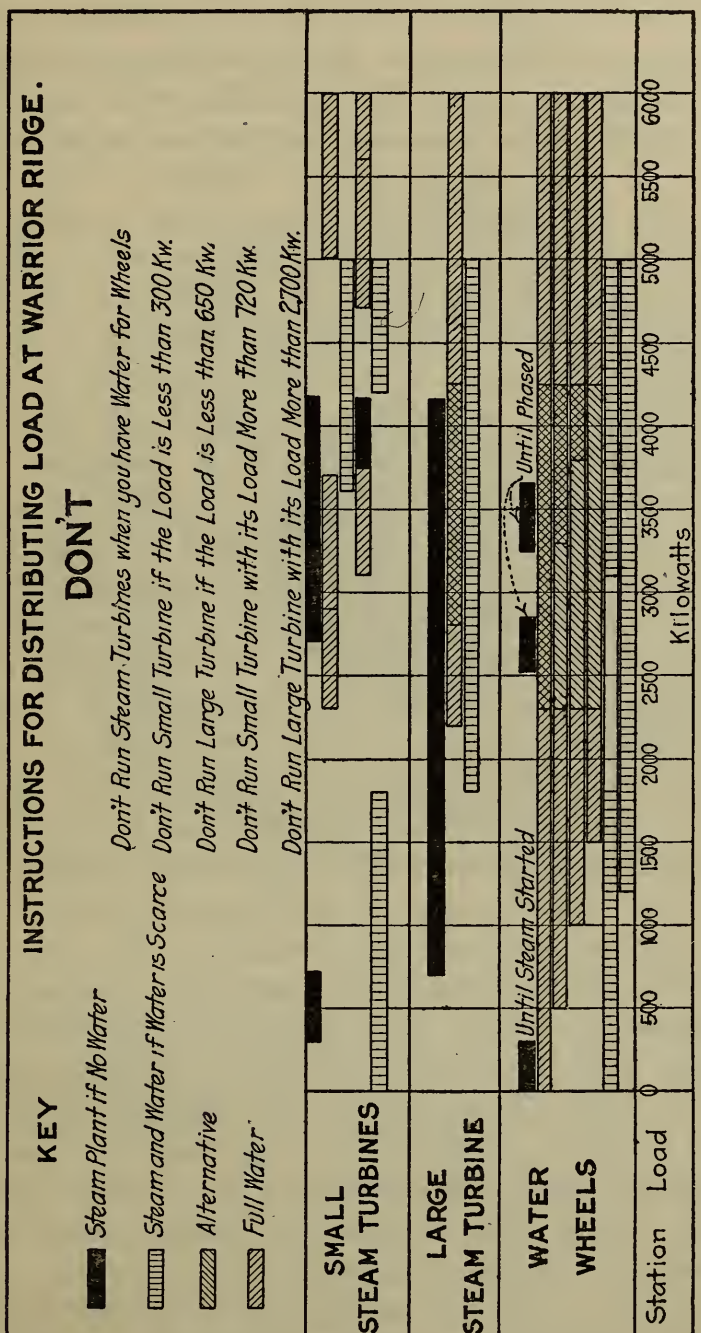


FIG. 66.—GRAPHIC INSTRUCTION

In order to secure maximum operating economy in a combined hydro-electric and carbo-electric plant, the operating engineer first consults the diagram of water power available (Fig. 63), and then combines the steam and water turbines by this instruction to meet the requirements of load.

engaged in the industry. This benefit is derived by them not only as members of the community receiving better and cheaper service, but in a most direct and immediate way in the form of increased compensation commensurate with increased value of their serv-

ice. Moreover, training affords them the development of a higher skill and better understanding of industry with consequently increased opportunities for desirable employment.

In this connection it is pertinent to refer to an old unfortunate term of "transfer of skill" as used by the committee of The American Society of Mechanical Engineers investigating the science of management and by Professor Malcolm Keir whose essay on the subject is an amazing mixture of deep foresight and ignorance of some phases of the subject. The vulgar conception is that the "skill" is in some clever manner taken away from workmen possessing it and "transferred" to the machine or to the owner of the machines. Such error is chiefly based on old, undefendable fallacy that the efficiency of an automatic machine is independent of the operator while in reality this doctrine is chiefly responsible for most of the industrial mismanagement and waste of natural resources. Any course of apprenticeship indeed, whether conducted by a guild, trade union, or employers, does "transfer" skill from the master or instructor to the apprentice. There is nothing novel in "scientific management" so far as it adopts the plan of vocational training with reward to those who learn. On the other hand, of any mechanical invention, whether that of Gutenberg or Lilienthal, it may be said that it transfers the skill of a penman or of a bird to a printing or flying machine, accomplishing the aim in a far superior way. Yet in such a transfer the elements peculiar to "scientific" management are notoriously absent. Curiously enough the scientific way of training men under a new mode of management begins with skepticism as to the very existence of such skill in workman's possession. Indeed, when tests and studies are made, they usually disclose that most of the processes, tools, motions, and habits of doing things are *not skillful,* that they are based on an imperfect knowledge, wrong training, and unfit traditions surviving from the times when means and methods were vastly different, by now obsolete and usually limited to individual experience, lacking broad knowledge, etc. Then the scientific research leads to improvements in method, based on an accurate knowledge of facts, such as the art of cutting metals devised by Dr. Taylor and his associates, or brick-laying of Major F. B. Gilbreth, or our methods of power generation, etc. Thus it is not *the existing skill* but a *new superior skill* that is developed and made use of in the application of science to industrial management. Hence, it is absurd to

talk of *transfer* first, because this skill was not in existence but newly developed, and second, because it is not possible to transfer a non-existing thing to someone. A more correct position would be to admit that the imperfect, casual, and scattered skill of the art is perfected, and the knowledge of *how to do* the work is bound and supplemented by an understanding as to *why*.

The role of an expert in this case is changed from that of an augur, closely guarding his trade secrets, however fallacious and

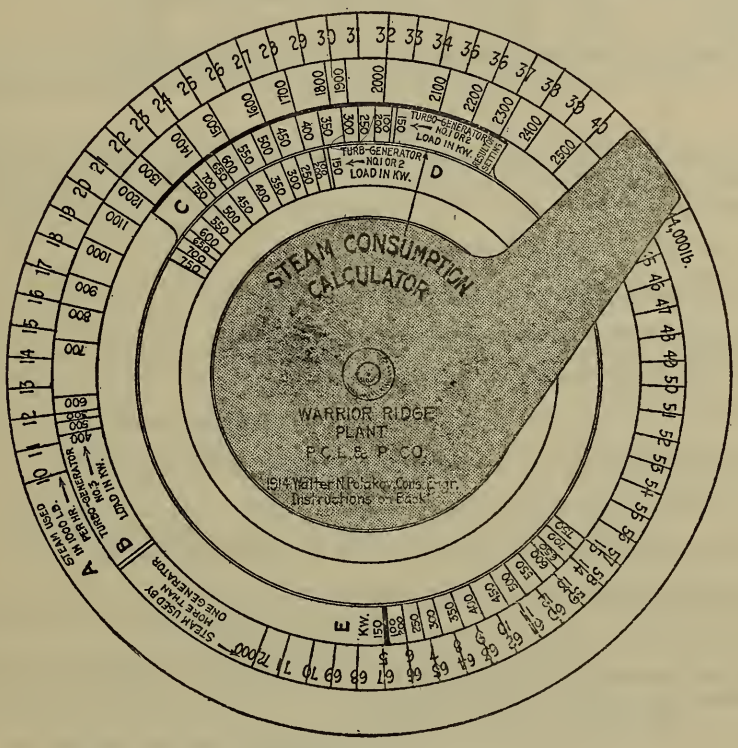


FIG. 67.—STEAM CONSUMPTION CALCULATOR

Hourly steam consumption of turbines varies as product of load (Kw) and water-rate (lbs. Kw). With two or more units total load may be distributed so that more or less steam will be used for the same output. In order to determine distribution of load among several units most economically without lengthy calculations special calculators may be prepared for any plant.

imperfect, to that of a *leader who enjoys an authority of one who knows what to do and how to do it.* His work benefits the community and brings him a higher reward than his privilege of keeping secret his knowledge can possibly do. The inconsistency of this theory of transfer of skill, frequently used by ignorant or unscrupulous writers and speakers to prejudice labor against the advancement in art and technique, is particularly pronounced in the power-plant work. The work of the best skilled stoker unaided by instruments and scientific training is hardly any

thing more than a rude guess and his skill is limited to mere dexterity and alertness in shoveling coal into the furnace and

Form 8A88T 5-C 4-9-12

INSTRUCTION CARD

Account No._____ Order No._____

Sheet No._____ _____ Sheets.

To be done by: Firemen Department: Electric Wanted Daily

For Gordon-Fulton Broad Top Coal Only.

Load	1200KW.	1450KW.	1750KW.	2000KW.	2300KW.	2800KW. up
Draft at uptake	.35	.40	.45	.55	.62	.71
Thickness of fires	6"	7"	7"	8"	9"	10"
Shake grates every	2 Hrs.	1½ hr.	1¼ hr.	1 hr.	40 min.	30 min.

D'E T A I L S

1. After shaking grates, take scraper, push fires to the rear lift and take out scraper without touching fires, throw green coal in front to required thickness, spread lightly in the rear.
2. Fuel bed must be level all the time.
3. Clean fires every 12 hours on load less than 2000 KW.
4. Clean fires every 8 hours on load more than 2000 KW.
5. Throw coal in fires every time the bell rings.
6. Only one fire door can be opened at a time in the boiler room.
7. Right proportion of coal - one wheelbarrow to one water weigher dump.
8. Feed continuously; not from time to time.
9. On sudden peaks allow water level to go to the lower mark.
10. On light loads keep water level at upper mark.
11. When shifts are changed have water level on middle mark.
12. Blow down boilers by opening blow-off valves slowly and closing also slowly allowing 2 minutes per boiler. Start 11:30 P.M.
13. Blow soot at 5:30 P.M. 5:30 A.M. and 12 noon. Follow special instructions.
14. Blow off superheaters every Monday at 9:00 A.M.
15. Report on duty daily: 6:55 A.M. 2:53 P.M. 10:53 P.M.
    Leave duty daily: 3:00 P.M. 11:00 P.M. 7:00 A.M.

CONDITIONS

1. Task means following exactly the above instruction; efficiency will be 71%.
2. Bonus is paid 25% of hourly rate if task is lived up to.
3. Bonus is forfeited if steam pressure drops below 165 pound square inch.
4. Report at once anything that is in the way to earn bonus if not reported no bonus will be allowed.

FIG. 68.—INSTRUCTION CARD FOR FIREMEN

Method of firing, strength of draft, frequency of slicing, shaking or removing clinkers, etc., vary not only with the rate of firing, i.e., load carried, but with grade of coal used as well. The above card was prepared for hand-fired Edgemoor boilers of 100 sq. ft. grate area.

pulling out ashes and clinkers. He may be able to maintain steam pressure and evenly feed water into boilers, but all that saves no coal, no miners and railroaders work, does not reduce

cost of living and certainly does not reduce his own hardships. The transfer of such "skill" from an old timer to a green man takes a long time and when completed both men waste the fuel at an equally appalling rate as compared with the possi-

Form SABST 5-04-9-12

INSTRUCTION CARD

Account No._____ Order No._____

Sheet No._____ _____Sheets.

To be done by : FIREMEN in Power Plant Dept: Electric Wanted Daily

1. Carry even load on each boiler in the neighborhood of 10,000 pounds of steam flow per hour, banking one boiler, if necessary, to secure the desired load on each unit.

2. Use coal in mixture of five parts of anthracite buckwheat #3 and one part bituminous run of mine.

3. Feed water evenly permitting extra gauge when the load drops and allowing one gauge below normal in case of sudden pick.

4. Fire at the rate of eight to ten shovelfulls spreading same evenly over fires, starting from rear and covering the edges of the grates and all blow-holes.

5. After each firing look at the instrument board and adjust, if necessary, the damper draft and ash pit pressure according to table for observed rate of steam flow. Maintain in furnace balanced draft as near as possible.

6. Regulate conditions as follows:

WHEN:	Flow per boiler is 8000	9000	10000	11000	12000 pound/hour
THEN	Ash pit must be 1.2	1.4	1.5	1.6	1.8
	Damper must be 0.03	0.04	0.05	0.08	0.10
	Fuel bed must be 3"	4"	5"	6"	7"

7. Levelling fires before firing, if necessary, shall cover blow-holes or puffed spots, don't plow or mix coal strata.

8. Record the readings every half hour on the boiler house log.

9. Never allow the steam pressure to drop below 140 pound square inch.

CONDITIONS

The above conditions shall constitute the firemen's task in addition to such regulations as to hours of work, etc. as covered by special instruction. The efficiency is expected to be 75% or more.

FIG. 69.—INSTRUCTION CARD FOR FIREMEN

This instruction card was prepared to cover certain conditions in a plant with hand-fired vertical Manning type boilers. The instrument board in this plant is shown on Fig. 62.

bilities demonstrated by firemen scientifically taught to work efficiently.

Still another consideration merits brief reference. The introduction of automatic machinery to which the designers passed their skill does not obviate or even diminish the demand for highly-skilled attendance. Contrary to this illusion, the more automatic, more complex and delicate is the piece of mechanism the more intelli-

gent and skilled must be the maintenance man, the electrician, millwright, the mechanic and the operator. An expensive mechanism trusted to a "cheap" man fails to render full value; an automatic stoker taking place of hand firing invariably wastes more fuel unless is operated by highly trained men, and not infrequently in larger stations these are college graduates.

Again, the fear that new mechanical devices will cause suffering to the working class through denial of employment to less skilled common labor is even less warranted than the similar feeling during the last century against the introduction of machinery. In America unskilled help has always been scarce and mostly imported by large corporations who taking temporary advantage of the foreign exchange made meager wages in dollars appear attractive in lires, crowns, or roubles, while now with export exceeding the import of "common" workers they are already at a premium. The advent of linotype, laundry machinery and particularly electric trolley cars and automobiles definitely dismissed unfounded concerns as to the fate of replaced labor. The stable men, the manure handlers, wagon and harness makers lost their jobs only to be reemployed, together with many more, as car builders, automobile mechanics, garage men, central station and oil refinery employees, chemical workers, etc. New jobs and trades sprang into existence paying better wages and offering shorter hours and better conditions as compared with discontinued occupations. The chauffeurs of today would scoff at an offer of a position as a coachman.

The deep significance of this process of "transferring skill" lies in the fact that this transferring is going in both directions: from universal labor and generations of dead engineers and scientists to coöperative living labor which means coöperation of scientists with workers and reverse. While the theory is modified by experience, the experience is peeled off from the crust of old traditions, habits, fallacies and customs of the trade, which were inherited from times when means and conditions of work were vastly different. This standardization of processes is comparatively a new conception and care should be taken to avoid an illusion that standard method is something permanent and unalterable.

Method is a mode of action, it is a living thing and as such is subject to constant development and modification. With each change in surrounding conditions, appliances and materials used, new discoveries made, etc., the method of work or opera-

tion should be revised and modernized. As soon as this principle is lost sight of, the whole organization becomes a dead "system" and a plant carrying it to a letter is like Rip Van Winkle falling behind the time while the world moves on. While the plant office is the custodian of all knowledge available, the study-man in coöperation with the entire force is keeping vigilance on every possible progress and modifies the practice as and when conditions and requirements change.

DEPARTMENT Power Plant
OPERATION Passing Coal
OPERATIVE M. Dearing
IMPLEMENTS Wheel-barrow holding 400 lbs. coal. Drawing 115 lbs. on arms when lifted. Shovel used holds 22½ lbs. of coal when full 50"
MATERIALS R. of M. Coal
CONDITIONS—
AT START Work in shade of Trestle 73° F.
AT FINISH Sun shines in Bin. Wind 86° F.
REMARKS: The operator has already been instructed and trained new method and so accustomed to it after 15, 25, 33, 41, 49, 57 etc. loads were brought in.

DETAIL OPERATIONS Wheeling Coal CARD No. 714

A Get tools ready.
B Check Scales
C Place diversion boards
D Shovel coal on Wheel-barrow
E Left wheel-barrow and place on scales
F Balance by adding or removing coal
G Wheel to front of Boiler
H Dump load and straighten wheel-barrow
I Wheel back to the Bin
Rest, sitting, per instruction
K Lock up the bin, sweep floor, put tools away.
L Turn in Key and Report.

SEE SKETCH CARD NO. .....

SUMMARY

	A		B		C		D		E		F		G		H		I		J		K		L	
TOTAL NO. OBSERVATION	25		25		25		55		55		55		55		55		55		5		10		8	
MINIMUM TIMES	No.	Time	No.	Time	No.	Time	No.	Time	No.	Time	No.	Time	No.	Time	No.	Time	No.	Time	No.	Time	No.	Time	No.	Time
	2	.44	4	3.7	3	.23	1	1.38	3	.18	7	.11	6	.10	3	.12	4	.13	4	10.0	2	11.0	1	1.2
	5	.42	9	2.7	5	.21	20	1.30	13	.16	11	.35	15	.12	13	.10	17	.15	1	11.0	4	10.5	2	.7
	11	.38	6	2.0	17	.11	30	1.25	37	.11	26	.31	27	.14	37	.09	31	.17		.	3	9.0	5	.5
	7	.35	6	1.8			4	1.21	2	.09	11	.28	6	.17	2	.07	3	.22			1	8.5	2	.3
TIME NECESSARY		.38		2.0		.18		1.25		.12		.33		.16		.10		.18		10.0		9.0		0.5
ALLOTTED TIME		4.0		2.0		.18	←					2.55 min.					→				←	10.0 min.		
	Once per Shift						Repeat Operation										Periodic				Once per Shift			

FIG. 70.—TIME STUDY SHEET (FRONT)

One of a large number of time studies made to study the job of coal passing. Shovel used is shown on Fig. 54 (right); wheelbarrow of special design holds 400 lbs. coal net; when lifted throws 115 lbs. on arms (58 each). On basis of such repeated observations, instruction card for passing coal (Fig. 71) was prepared.

With the preparation of clear and complete instructions, the work of mastering the processes is not completed—it only really starts at this moment. To assure the proper use of knowledge and living up to instructions prepared, the training of employees and stimulation of interest should receive full share of attention. Inasmuch as the least skilled and most backward men should require more help from instructors, in order to bring the level of efficiency up to the standard, it has been found beneficial to reward this spirit of helpfulness by special recognition to instructors. To that end the instructor receives over and above his salary an extra remuneration for each man who learns

to perform the work with the predetermined degree of efficiency, and double reward for every man under his instructions on the days when all men live up to their tasks.

The value of a careful, systematic and prolonged training of the employees cannot be over-emphasized. The most diffi-

FORM NO ...1... SHEETS SHEET NO. 1 ..... DISTRICT ..... DEPARTMENT

GENERAL INSTRUCTION CARD

ORDER NO. ..... OPERATION SYMBOL .....

DESCRIPTION OF OPERATION Passing Coal from Coal Bin to Front of Boilers in 400 lb. Wheelbarrow on Concrete Floor

6.42 A.M. 3.00 P.M.
2.42 P.M. 11.00 P.M.
TO BE STARTED 10.42 P.M. TO BE COMPLETED 7.00 A.M.

YEAR	MONTH	DAY	SIGNED W.N.P.
13	10	13	CHECKED

ITEM	DETAILED INSTRUCTION	Unit Time	Time Allowed
1	Get Shovel, long Handle, 21.5 lb. Capacity		
2	Get Wheelbarrow, 400 lb. Capacity		
3	Check the Scales, get the Report Sheet and Pencil	4.00 Min.	
4	Open the Door of your Coal Bin	2.00 "	
5	Place Board to Stock Coal for Next Fireman	0.18 "	
6	Shovel Coal in Wheelbarrow	1.25 "	
7	Lift Wheelbarrow on Scale	0.12 "	
8	Weigh by Dropping or Adding Coal	0.33 "	
9	Wheel to Front of Boiler	0.16 "	
10	Dump and Lift Wheelbarrow	0.10 "	
11	Wheel Back to Bin	0.18 "	
12	Total Time per Wheelbarrow, with 20% for Incidents	2.55 "	45 Min.
13	After 15 Wheelbarrows Delivered, Rest Sitting	10.00 "	55 "
14	Pass 10 Wheelbarrows per Above Detail Instruction	25.5 "	1 Hr 20 "
15	Rest Sitting	10.0 "	1 " 30 "
16	Pass 8 Wheelbarrows as per Above Instruction	20.0 "	1 " 40 "
17	Rest Sitting	10.0 "	1 " 50 "
18	Pass 8 Wheelbarrows as per Above Instruction	20.0 "	2 " 10 "
19	Continue Above Operations until enough Coal is Passed	Same Allowance	
20	Sweep Floor, Get Tools in Shape, Lock Bin Door,	10.0 "	
21	Return the Key of the Bin and Report to the Office	10.0 "	
22			
23	Task is accomplished when within 8.3 hrs. all Coal		
24	Needed is Passed without Delays for Firemen's Work		
25	and Instructions Observed		
26	Bonus is Paid Over and Above Day Rate 1¢ per 1000 lb.		
27	of Coal Passed During the Shift if Accuracy of Reports		
28	is within 2% of Railroad Weight.		

THE ABOVE WORK COMPLETED AS DESCRIBED ABOVE Signed Walter N Polakov

FIG. 71.—INSTRUCTION CARD FOR COAL PASSERS

Periodic rest sitting is a necessity for conserving human energy and preventing fatigue. The above instruction card is prepared on the basis of time studies similar to that on Fig. 70. It was found easier to deliver 65,000 lbs. of coal in 8 hours than 45,000 lbs. of coal in 12 hours.

cult part of this work is breaking the old habits. The restraint from the habitual actions often makes the employee nervous even if he is thoroughly convinced of the advantages of the new method. If, however, the new way appears to him as an unreasonable fancy of his superior, who failed to make it clear to him that the change is reasonable and to mutual advantages, the strain on his nerves caused by both suspicion as to the

outcome and concentration of mind on unfamiliar actions may take the form of concealed sarcasm or even assume an unfriendly attitude. It would be manifestly erroneous to think that the job of an instructor is a temporary one. It is as permanent as the plant itself, inasmuch as men, supplies, conditions and requirements gradually change; new investigations should be carried out, and to meet the changing circumstances the manage-

BEST LOAD
FIREMEN'S
INDICATOR
THICKNESS OF COAL ON GRATE, INCHES
DRAFT REQUIRED IN TENTHS OF AN INCH WATER
STEAM FLOW 1000 LB. PER HOUR

FIG. 72.—FIREMEN'S INDICATOR

With variable steam demand and constant area of grates the rate of combustion should be changed with the rate of steam generation. To maintain at the same time uniformly good economy, the thickness of coal on the grates and the amount of air needed for complete combustion should be adjusted in a definite relation. The instructions to that effect are given by placing corresponding additional scales on the dial of the steam flow meter. Similar arrangements are devised for mechanical stokers or fuel oil atomizers.

ment must convey the revised information to the men, constantly making available the gain in knowledge.

In the preceding chapter, the task was defined as *doing the work in the best devised manner* as opposed to the old conception of a task as a request to accomplish *the most work.* Taylor himself had to admit that his "tasks were all purposely made so severe that not more than one out of every five workmen could live up to it." Contrary to this our *quality tasks*

are set so that anyone, unless he is physically or mentally disqualified for the work, can accomplish his task with comparative ease. Obviously in power generation quality means vastly more than quantity, hence the paramount function of administration is the training of employee not only in proper methods of work and forming better habits, but particularly in teaching the scientific rudiments and principles, clear understanding of which is so essential for intelligent performing the work. It is therefore the task of the management to offer the employee an opportunity to do the kind of work for which the man has inclination and is fitted; next, to provide means and surroundings that facilitate the work and assure the possibility of good results; and finally to assume the full responsibility of seeing that the work is properly performed. In practice it means:

1 Helping the employees to acquire correct and useful knowledge

2 Helping the employees to cultivate the habit of doing good work

3 Rewarding the meritorious work.

Progress Due to Training

The opportunities for conserving human efforts and natural resources, realized through a careful training of workers in performing their function in the proper way, can be correctly estimated from a review of a few typical instances. No man without thorough and prolonged training can acquire the new habits, and it is really the habit of work and habit of new way of thinking that shall be aimed at in this work. We may know the truth, we may be convinced of it yet, if we are not in the habit of practicing it—all wisdom and truth is of no avail. It is universally conceded that the good results obtained during the boiler tests are never, or only seldom, duplicated in the everyday practice. Yet, if the conditions of load and service during the test were normal working requirements, there is no other reason for results falling short but the failure of the regular crew to carry on the work the way it has been done during the experiments. Many may be the reasons for it: lack of means, knowledge, incentive, etc., but the fundamental and the most common one is the failure of the management to assist the men until the new practice becomes second nature with them. The

results of this aptitude to expect good results after hurriedly starting men on work as per instruction card are sometimes very harmful and may bring the whole work into disrepute unless quickly discovered and mistakes rectified.

The following quotation from a report made on the case in question is self explanatory: "180,000 pounds of coal were handled by four men in 24 hours. Two men working together 12 hours each day and passing 45,000 pounds each, could not stand the work; it was too hard. This was because the shovel had a short handle and they had to bend too low; the shovel held only 16 pounds of coal instead of 21.5 pounds causing the workman to bend too many times per ton; the wheelbarrow held only 250 pounds, causing too many trips. When the man was given the right kind of a shovel and wheelbarrow holding 400 pounds, yet throwing less weight on his arm when lifted, he handled 65,000 pounds in 8 hours (instead of 45,000 in 12 hours) and found his job much easier than before. This man, however, was left to himself before the new way of doing the work formed a habit with him. In a short time he came to us complaining of fatigue and refusing to continue the work. We started to watch him again, and the trouble was clear. He did not observe the instruction card. This card ordered rest every so often, for so many minutes, sitting. Instead, the man worked much longer at a stretch, thinking that longer rest afterward would refresh him better, and when resting he spent the time standing and chatting to a fellow worker and not sitting as prescribed. That was enough to cause fatigue. The rest of the gang of coal passers at Warrior Ridge were finally put on the task in the proper manner, and no complaint has since been heard, while their health and spirits markedly improved." (See Figure 71.)

Still more serious mistakes can be made by the management failing to appreciate the value of improved work of men. Once the operation is studied a new method of performing the work discovered and its advantages evaluated, the men should share in the benefits accrued from their additional skill. The men know just as well as the management what their additional skill is worth for they keep pretty accurate check on the amount of coal used for carrying certain load. If as a result of better work and closer attention on their part they succeed in saving a few tons of coal, they know that while in a measure it is due to the facilities and instructions provided by the man-

agement the saving came ultimately as a result of their own skill and good will. They are entirely willing to divide the savings in some equitable manner but it is unreasonable to expect them to stand for any thing short of fair play.

An instructive occurrence happened in a New England mill-plant illustrating the reaction of men to an attempt to cut their "quality-bonus" or secondary rate paid for extra skill, down to a figure unreasonably meager in comparison with the saving in fuel resulting from their efforts. The history of the case can readily be seen from the bonus record reproduced in Figures 73, 74 and 75. Upon the completion of tests and experiments, covering in total thirty-three boilers and furnace tests with various available fuels, under different modes of firing and carrying various loads, a definite practice was devised and accepted as standard. Following the prepared instructions would result in a 72 per cent boiler and furnace efficiency, or higher if there was an unusual combination of favorable conditions. On September 30, 1917, the actual training of firemen was started and the record of their accomplishments was kept. As some of the men participating in the research work already had a clear understanding of the new method the progress was very rapid and results quite gratifying, the efficiency averaged 74.3 per cent for four weeks, and 63.8 per cent of all the men in the gang succeeded in doing meritorious work as shown by the black squares on the record; the thin lines indicating dangerously low efficiency (below standard). On October 1, 1917, it became known in the boiler house that the management had decided to pay a smaller secondary rate for extra skill (40 cents per day to head firemen and 30 cents to helpers instead of 60 and 50 cents as it was originally understood.) A decided disappointment was at once manifest, the men lost interest in the work, respect for the management and rapidly returned to the old manner of tending boilers with resulting efficiency sliding down as low as 66.5 per cent which was about the average figure of the preceding year. When questioned as to the motives of this deliberate neglect an old Yankee firemen readily gave his account. "The company," he said, "struck a bargain with men whereby they had agreed to save seven wheelbarrows of coal per shift for 60 cents; the men learned how to do it; now the company is a quitter, does not keep its word and need not be treated better than a yellow dog."

The management, after fourteen weeks, realized their blunder;

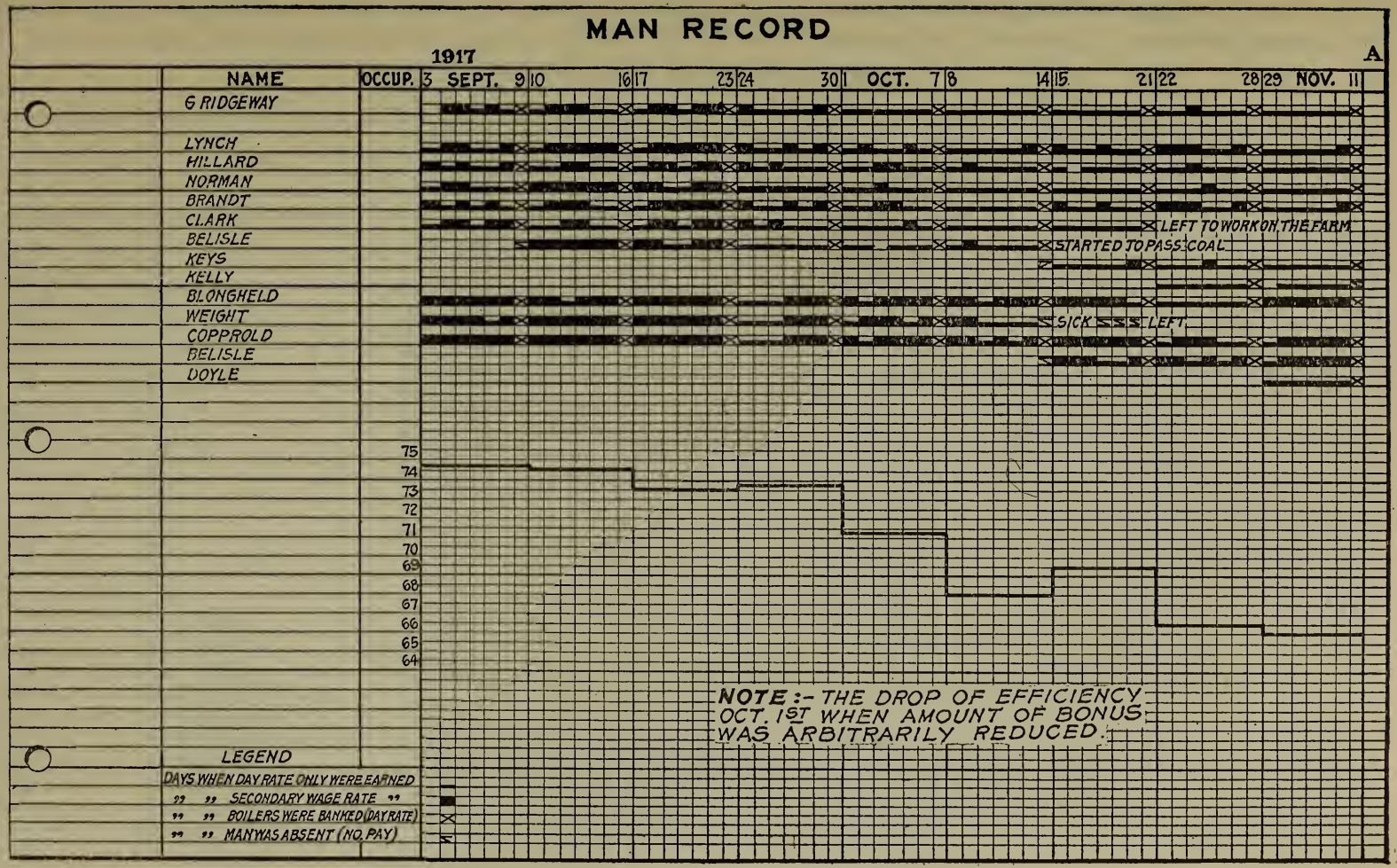


FIG. 73.—MAN RECORD

Effect of reduction of bonus beginning the last week of September is clearly indicated by a rapid drop of efficiency by the disinterested and disheartened personnel, preferring to lose their bonus than to submit to unfair play.

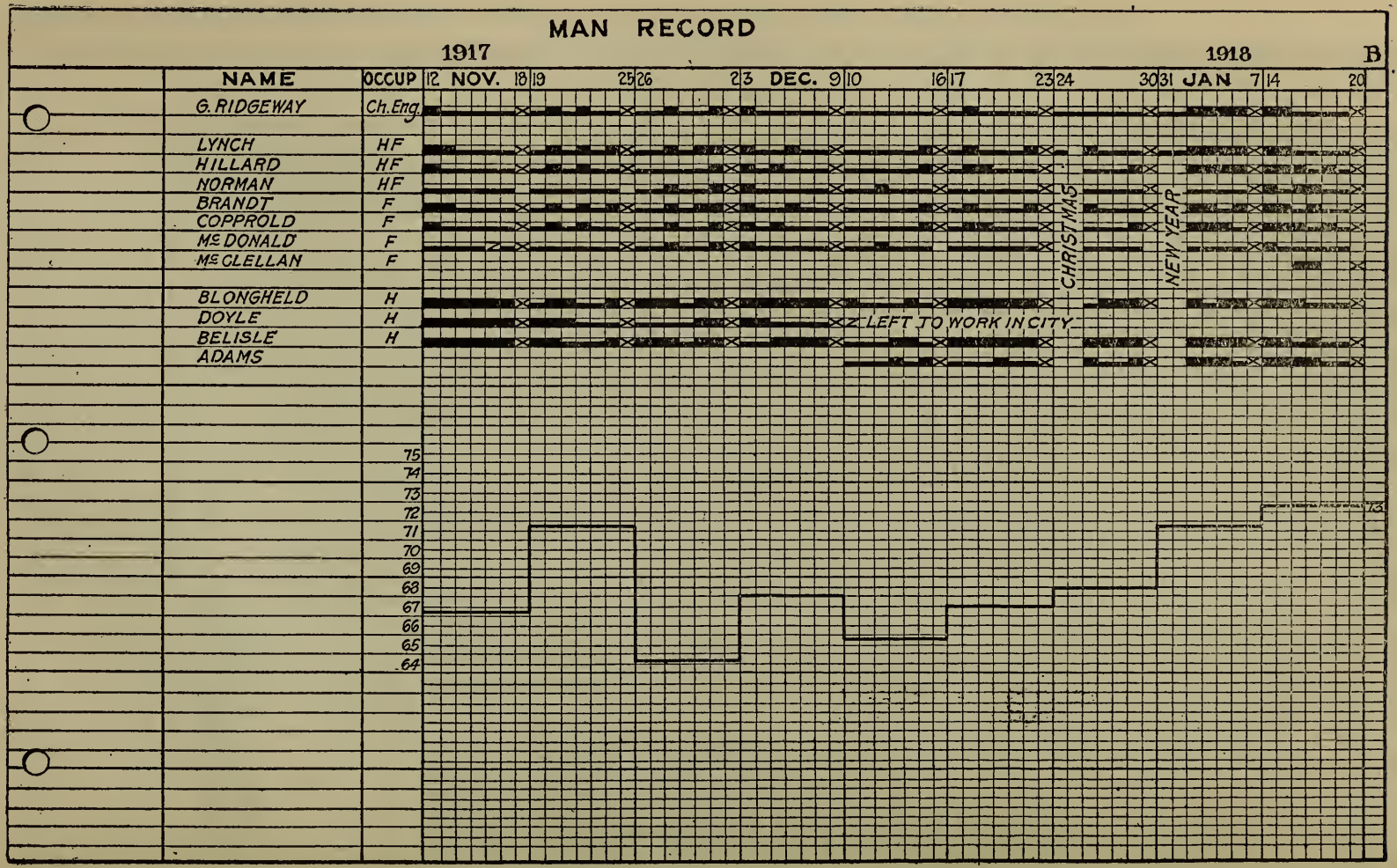


FIG. 74.—MAN RECORD (*Continued*)

Until the end of the year the same set of men as shown in Fig. 73, maintained efficiency below 68%. Beginning January, 1918, the originally agreed bonus was reinstalled with immediate response from the men, bringing efficiency to 72%.

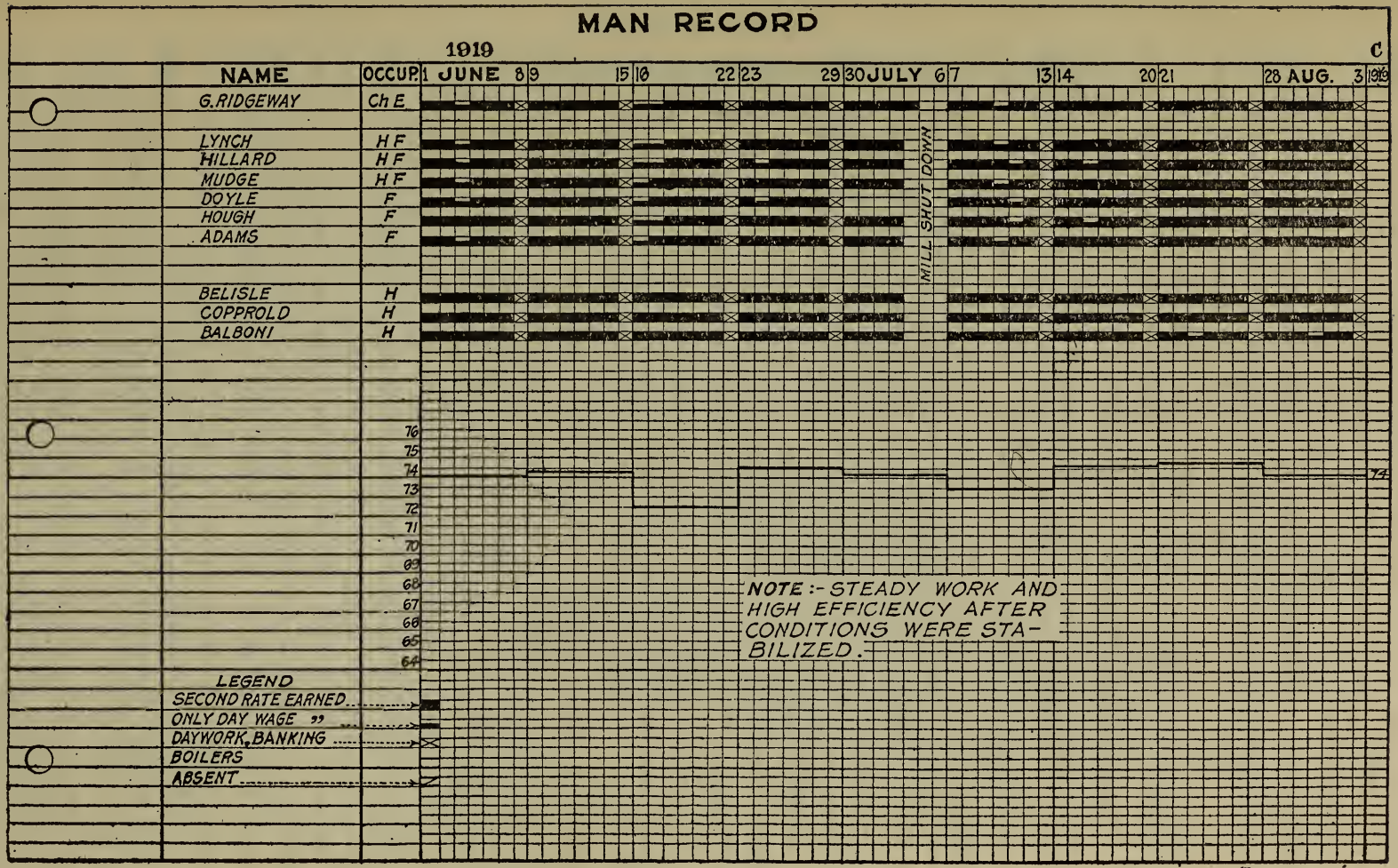


FIG. 75.—MAN RECORD (*continued*)

Several months after, substantially the same crew, fully developed the new habit of industry and maintained steady high efficiency losing bonus only on rare occasions.

a saving of $50.40 in bonus during this time cost them about $2,275.00 in coal and the respect of nearly all the men. In January, 1918, the bonus was reinstated as agreed and the record reproduced in Figure 74 shows that the men quickly responded and coöperated with the engineering staff in maintaining uniformly high efficiency averaging thereafter about 74 per cent. Figure 75 shows the record of the same company and the same head firemen more than two years after.

Still another rock on which the conservation campaign can easily be wrecked is the lack of coöperation on the part of management in maintaining the equipment in first-class operating condition. A large power plant, whose upkeep was entrusted to an old-fashioned master mechanic, taking care of all other departments of the concern as well, was run on the principle that no money shall be spent for maintenance until something broke down. When better operating methods were inaugurated assurances were made that the maintenance service would be carried according to our schedules. This, however, was delayed for several months and meanwhile the efficiency of operation gradually improved by the splendid coöperation of operating force. Figure 76 indicates this gradual improvement which, however, after reaching a point short of possible perfection, rapidly collapsed due to utter neglect to keep up the equipment in proper repair. In six months of supreme efforts and hard work the efficiency could not be brought above 57 per cent in a poorly maintained plant. It took four months to organize store-room and repair service and within next four months the efficiency was easily built up from 48 to 67 per cent. After several months of extensive repair work finally carried out in compliance with our schedules, work has resumed and the operating records reproduced in Figure 77, show the level of efficiency finally attained.

Whenever the plant administration accepts its share of responsibility and properly performs its duty to provide proper instruction and training to offer adequate compensation for skill over and above the time paid for, and to keep the equipment as well as all other material and physical condition fit for work, then the results forthcoming are gratifying to all concerned.

In this connection a few actual cases may well serve to prove the statement that correct understanding and intelligent mastering of processes increases productivity of existing equipment, reduces waste and consequently expenses, and, among other results, increases value of labor, reduces fatigue or length of work-

ing day, provides interest in occupations, introduces greater safety, and ultimately reduces the cost of production, thereby rendering a manifold service to the community.

A characteristic case was described in the following report of a general works superintendent to the president of a company who adopted in their plant our principles and for some time practiced our methods:

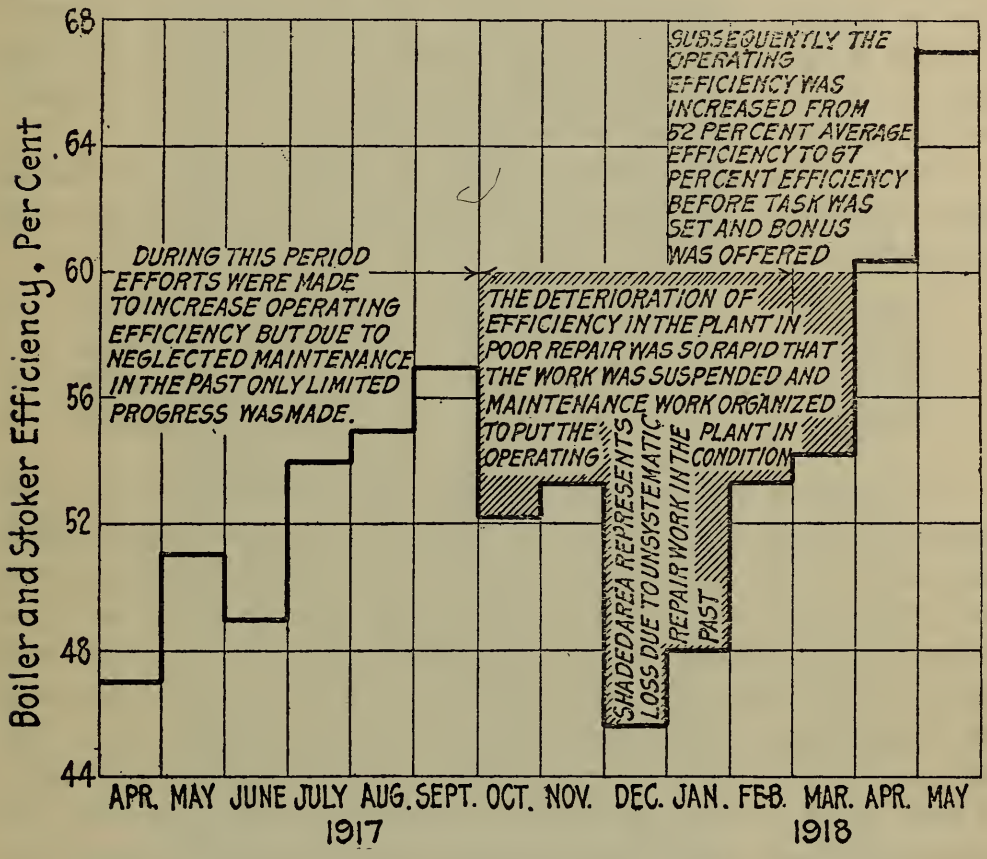

Boiler and Stoker Efficiency, Per Cent
68
64
60
56
52
48
44
APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY
1917
1918
DURING THIS PERIOD EFFORTS WERE MADE TO INCREASE OPERATING EFFICIENCY BUT DUE TO NEGLECTED MAINTENANCE IN THE PAST ONLY LIMITED PROGRESS WAS MADE.
THE DETERIORATION OF EFFICIENCY IN THE PLANT IN POOR REPAIR WAS SO RAPID THAT THE WORK WAS SUSPENDED AND MAINTENANCE WORK ORGANIZED TO PUT THE OPERATING PLANT IN CONDITION
SHADED AREA REPRESENTS LOSS DUE TO UNSYSTEMATIC REPAIR WORK IN THE PAST
SUBSEQUENTLY THE OPERATING EFFICIENCY WAS INCREASED FROM 52 PER CENT AVERAGE EFFICIENCY TO 67 PER CENT EFFICIENCY BEFORE TASK WAS SET AND BONUS WAS OFFERED

FIG. 76.—EFFECT OF POOR MAINTENANCE ON PLANT EFFICIENCY

For six months the efforts and gained knowledge of men gradually improved plant's thermal efficiency from 46% to 57%. Neglected maintenance brought about the collapse of efficiency and it took another six months to recommence the progress. Compare this case with a case of a public utility plant, the maintenance of which was also neglected and eventually caused shut down (Fig. 36).

"It is only fair at this time to call attention to the fact that the first fundamental of electric power, and all other power costs, has been very materially improved in the last year, namely, steam generation.

"Steam generated as related to coal burned is the one fundamental consideration in any power plant. Our coal utilization charts from October 22, 1918 to date show a steady improvement in obtaining more steam with each pound of coal. During the period, November,

1918, to February, 1919, the estimated loss, or amount below this figure was more than 100 tons per week, or $2,400.00 per month at present prices. This loss is now entirely eliminated and records show an even better evaporation than the standard set.

"When the fact is taken into consideration that in the early part of 1918 we were paying $3.98 per ton delivered for coal, and that to-day our contract calls for a price of $5.15 per ton delivered, it can be seen that even in the item of our principal raw material our cost is 30 per cent higher than under war conditions. During some of the latter months of 1918 our coal cost ran as high as $6.69 per ton delivered, on account of war conditions.

"During the first fifteen months the market price of power plant house labor has been increased slightly more than 50 per cent as follows:

Date	Firemen	Helpers	Laborers
March, 1918	33-35 cents	30 cents	27.5 cents
October, 1919	52-53 cents	45 cents	43.0 cents
Increase	53 per cent	50 per cent	56.5 per cent

"In spite of the increases in these two principal items our unit cost per 1000 pounds of steam for the last three months has averaged less than 50 cents per 1000 pounds of steam for the first time since we commenced to keep records of steam generated. When it is borne in mind that this has gradually been reduced from a high cost of $1.11 per 1000 pounds in December, 1918, it can be seen that the improvement has been marked. It might be noted here that this cost included all the costs of generating steam and transforming it into various forms of energy in which it is sent out from the power house and represents the total monthly cost of the power department divided by the total steam generated.

"The comparison for 1919 is as follows:

1919	Total Cost	Total Pounds Steam	Cost Per 1000 Pounds Steam
January	$24,096.27	25,381,000	$0.951
February	22,345.38	23,400,000	0.953
March	21,895.90	24,571,000	0.693
April	18,985.95	29,741,066	0.637
May	16,340.47	26,900,000	0.572
June	18,142.36	26,476,000	0.685
July	16,987.25	36,127,000	0.468
August	18,985.40	36,066,000	0.525
September	16,384.33	33,527,000	0.588

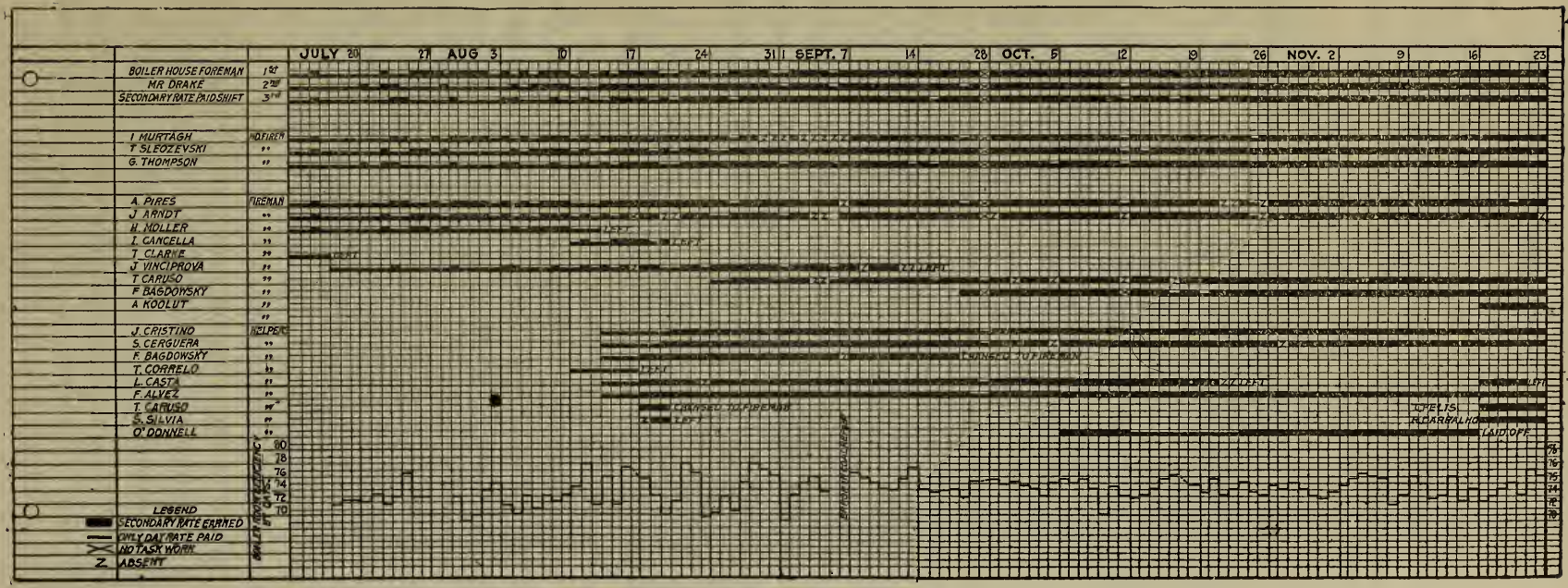


FIG. 77.—MAN RECORD CHART

Efficiency of men and their earning of the secondary wage rate is clearly shown on this record. Coal utilization charts of the same plant shown on Fig. 107 and 107*A*. It took about two months' time to ground the personnel in the new mode of working. Note the uniformity of efficiency toward the end of the chart as compared with the start in July-August.

In other words, in spite of increased cost of coal and other material, over 50 per cent higher wages per hour and from 60 cents to $1.75 bonus paid on top of the day wages, more than half of the expenses of power production were eliminated since formerly they represented pure waste. At the same time the factory's demand for power has incrased 80 per cent while the total cost of power department decreased from $24,000 to $17,000 per month-average."

A more complete story of actual results accomplished within two years of mastering power production according to the fundamentals advocated by us is told graphically in Figure 78. After almost a year spent in studies, organization of auxiliary departments, regulation of service and gaining confidence and coöperation of the employees a fairly rapid progress in bettering operating practice was made. The limit was reached however at about 67 per cent efficiency and only the payment of a secondary rate for applied skill finally secured the high efficiency of 74 per cent (includes economizers, boilers and stokers) and resulted in a uniformly satisfactory efficiency. The effect of using two-thirds of anthracite screening of low heating value instead of straight soft coal is seen in the decrease of evaporative ratio per pound but this had no effect on the thermal efficiency. Inasmuch as the use of anthracite coal was dictated not by considerations of economy but was at that time a measure of expediency, it being advisable to keep the factory in operation irrespective of disadvantageous coal prices.

In many instances haphazard operation of plants fails to secure full output of equipment, especially of boilers. The results of this ignorance as to what is the reasonable and economical load for boilers to carry are manifold; lack of spare boilers ranks first as it limits the time available for proper cleaning and maintenance, thus materially lowering operating efficiency; next in importance is that due to an excessive number of boilers on the line which causes a considerable lowering of operating efficiency and excessive use of fuel in boilers nearly banked. In extreme cases it appears that with an increased steam and power demand it is necessary to install additional boiler capacity—thus adding to the above losses a new one—of overhead charge on useless equipment.

A reference to a case of this character may not be without value. Several years ago, the author was consulted in regard to the contemplated additional installation of boilers in a plant furnishing a bleachery with steam and power. The plant contained ten Manning boilers equipped with Jones underfed stokers. A survey of the method of operating the boilers resulted in the condemnation of the plan of

adding new equipment. As a result of modified methods of management a materially increased demand of the bleachery is efficiently met by seven of the ten old boilers. The efficiency at the start had been found not to exceed 50 per cent and the men doing hard work on excessive number of boilers were not guided. Installation of instruments on the boiler control board enabled the author to start the

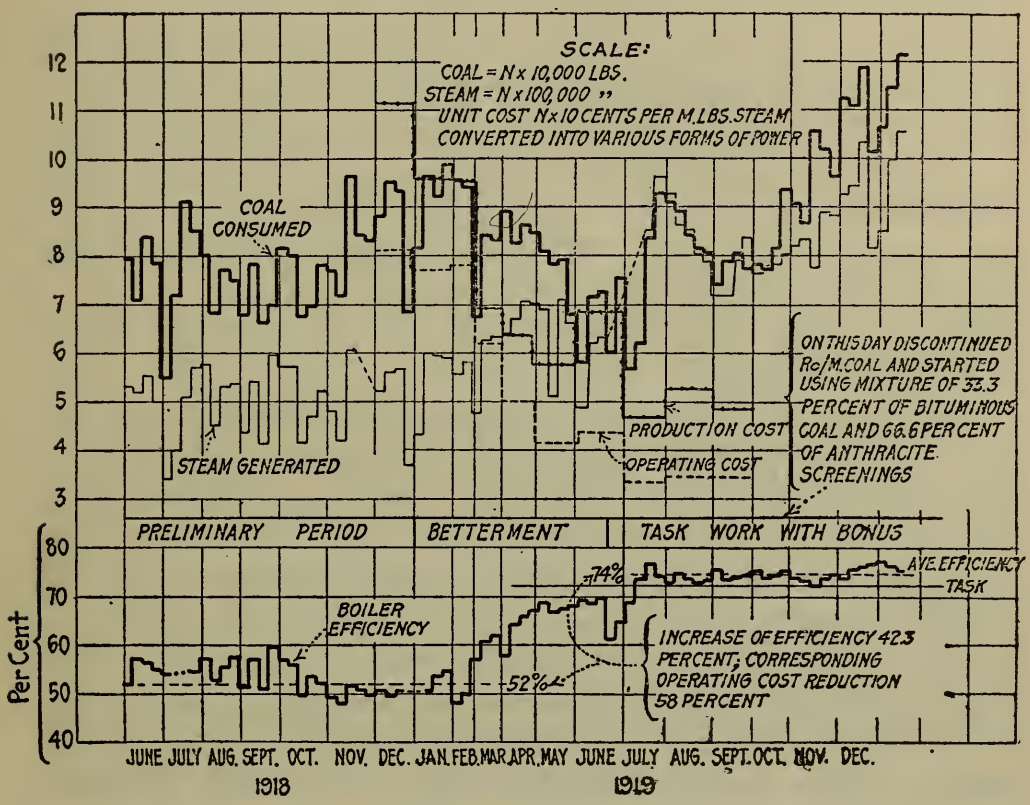


FIG. 78.—TWO-YEAR RECORD OF POWER PLANT PROGRESS

During eight months of preliminary period of studies and reorganization of auxiliary service boiler efficiency was 52%. It took five months more to teach men to secure 74% by following up our instructions. Consequently operating cost was reduced from 80c per M lbs. of steam converted to 34c, and the production cost per unit was cut in two in spite of increased cost of fuel and supplies and advanced wages and secondary rate paid.

necessary studies and the result of training the men in the intelligent use of the instruments raised the boiler efficiency from 50 to 60 per cent. Further progress was made with the able assistance of the plant superviser who carefully trained the men so that the weekly average of boiler efficiency was finally built up to about 73 per cent. Further progress was made along the lines of reducing steam consumption through more efficient means of distribution and utilization of power and live steam in processes as shown by Table I.

Figure 79 visualizes the case. For three months the operating efficiency fluctuated within a large range, high points being reached during the weeks of our demonstration tests. Beginning April the coöperation of the men was secured and the management exhibited increased interest in the work, being stimulated by the advance in the price of coal. The improvement in methods, however, progressed more rapidly than the war-price on coal; toward the end of 1916 difficulties of obtaining specified coal and the necessity of buying anthracite coal in the open market made necessary a change in fuel and while this has slightly depressed the thermal efficiency, the cost of coal per 1000 pounds steam at that time was 19.5 cents with the price of coal per ton nearly $6.30 as compared with old practice when with $5.05 per ton of better coal the cost of coal per 1000 pounds steam averaged 26.5 cents. With two adverse factors: lower heat value of coal and higher price per ton each thousand pounds of steam were made with 7 cents less coal used, equal to elimination of 35.9 per cent loss.

Figure 80 tells the story of offsetting the effect of increased cost of coal by means of training the management and men along the lines advocated by us. The heavy curve represents the actual reduction of cost of coal per 1000 pounds of steam while the two light curves illustrate the effect of the improvement in method if the price of coal remained either as it was at the beginning of our work or as we left it. It appears that when buying coal at $8.35 per ton the steam power cost less than it was when coal was purchased at $4.62 a ton.

While the above cited cases of plants of various sizes had mechanical stokers, another example of what our methods accomplish in a hand-fired, unusually well managed plant was recently reported by Mr. G. E. Williamson at the eleventh meeting of the technical association of the Paper and Pulp Industry.[111] The boiler plants referred to, due to the strict attention to operating practice, were operated before the work was started at efficiency averaging 67 per cent. Yet, he said, "their old methods, although a considerable advance over those existing in the majority of paper and pulp mill power plants, did not prove entirely sufficient, as we realized that the maximum possible efficiency was not being obtained. The results easily shown in tests did not remain as every-day performance, and the interest and enthusiasm aroused in the firemen at these times soon disappeared and with them the high evaporation and efficiency. How to bring about such conditions permanently became the problem.

"It was then necessary to run a large number of boiler tests with

different conditions of draft, forced-draft pressure, thickness of fires, rate of combustion, flue gas temperature, coal mixture, etc., before we were at all certain. It was necessary to run some thirty-odd boiler tests before we were at all certain that all variable conditions are accounted for and that we really know how to adjust the condition in order to secure the maximum efficiency at any rate of driving. Following these study tests, we ran a number of check tests to ascertain beyond doubt the possibility of attaining the predetermined results at will.

"When this part of the work was done, we were in a position to set the task for our firemen, which can be described as exact living up to instruction card.

"Once all prescribed conditions are fulfilled, the efficiency of 74 per cent or better necessarily follows.

". . . as the work progressed, it became a very important task of our supervisor to train the men to improve first one condition after another, until the everyday results obtained were comparable with those obtained under favorable test conditions.

"The next step was the determination of a suitable bonus for accomplishing the standard task. Men realize full well that if they save coal their service becomes more valuable to the company, hence they expect corresponding additional compensation or bonus."

What is probably of still greater importance was the company's clear realization that "the responsibility for inefficiency, waste of coal, loss of power, misuse of supplies, breakdowns, and interruptions to service falls on the management for it is plainly due to their neglect in any of the following respects:

1 Failure to devise efficient method

2 Failure to teach men good habits

3 Neglect to provide men with necessary instruments and incentive

4 Indifference to planning the work ahead

5 Faulty organization of auxiliary service

6 Improper selection, care, and issue of materials

7 Thoughtless distribution of load through the day, week and year.

The moral effect which these methods have produced are of interest. Here is a statement appearing in the employees' publication of this paper company which bears the witness:[112]

"In comparing this year's records with those of last year, we find that a saving of 12 per cent has been made in fuel. This does not mean that 12 per cent less steam was generated but it does mean that for the same amount of steam generated one-eighth of the coal was saved.

"What does this mean to you and to me from a patriotic point of view? Simply that this large pile of coal has been conserved for some other manufacturer to carry on his work."

It is not infrequently heard that while the opportunity for considerable improvement exists in the plants of manufacturing concerns, the same is not true in cases of public utility plants. The usual argument advanced is that the electric light and power companies can afford to employ better talent and use more advanced methods than the manufacturing concerns who regard their power departments merely as a "necessary evil" and pay little or no attention to how they are managed so long as they keep the factory running. The stereotyped statement from this class of officials is "We give a good deal of attention to the operation of our various power plants and we from time to time modernize them and bring them up to date."[113]

Figure 81 gives a conclusive answer to this conceited statement. The dotted line represents the net cost per kilowatt hour in the plant regarding which the above cited statement was made; the solid-line curve represents the reduction of operating expenses in another railroad central station managed under our supervision though without the opportunity of paying bonus. The data were compiled in both cases by a third and disinterested party (the Pennsylvania Railroad). Speaking from the broad experience in both central station work and manufacturing power plants, the opportunities for conserving natural resources and energy are larger in the public utility plants if not necessarily in percentages then always in totals. Even in cases where public utility's central stations are merely approached with the intention to only reduce the most obvious wastes, favorable results are readily attained without much effort. It is enough to mention well-known cases like that of the Philadelphia Electric Company; Denver Tramway Company; Manilla Electric Company, and the like, where betterment was carried along "home-made" lines.

In order to complete this review an extract from the paper read by Mr. J. C. Scholl before the Pennsylvania Electric Association at its eighth annual convention held at Bedford Springs, Pa., September 8-10, 1915, is of much interest. The abstract of this paper printed on January 18th, 1916, says: "the methods that produced the re-

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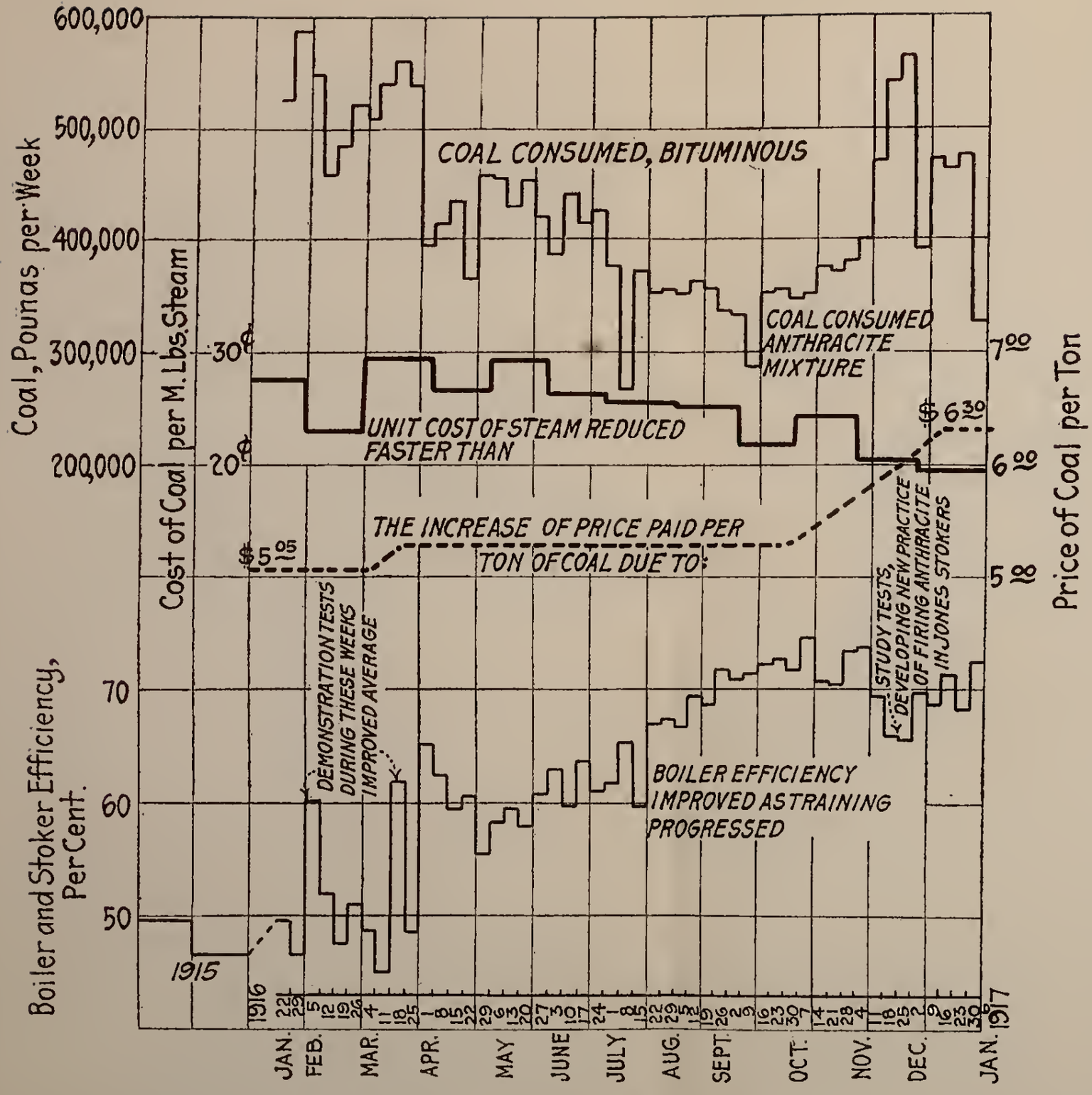


FIG. 79.—INCREASED EFFICIENCY AND REDUCED COAL CONSUMPTION

The average efficiency of the preceding year was under 50%. In the course of seven months 70% boiler and stoker efficiency was exceeded. In November it was necessary to use anthracite coal mixed with one-third bituminous. The new practice was successfully devised. Meanwhile price of coal gradually rose from $5.05 to $6.30 per ton yet unit cost of steam was reduced by about 7.5c per M lbs. of steam or over $4,000 a year.

Coal pounds per Week
Cost of Coal per M Lbs Steam
Boiler and Stoker Efficiency, per Cent.
500,000
400,000
300,000
200,000
70
60
50
1915
1916
1917
1918
JUNE
MAY
MAR
JAN
SEP
NOV

sults described in this paper were instituted by Walter N. Polakov, applied by him to the Warrior Ridge plant and fully described in a paper entitled Task Setting for Firemen, presented before the December, 1913, meeting of The American Society of Mechanical Engineers, also published in *Power,* December 23, 1913.—Editor."

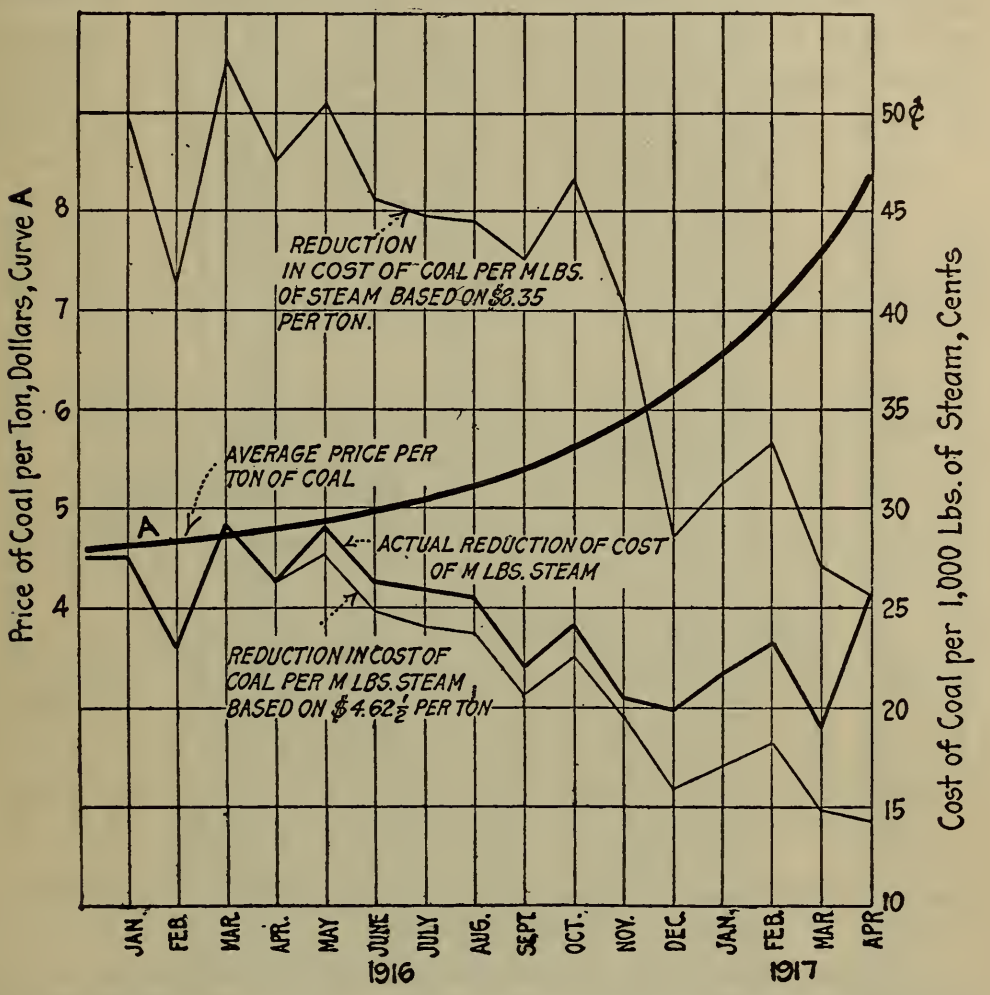

Price of Coal per Ton, Dollars, Curve A
Cost of Coal per 1,000 Lbs. of Steam, Cents
REDUCTION IN COST OF COAL PER M LBS. OF STEAM BASED ON $8.35 PER TON.
AVERAGE PRICE PER TON OF COAL
A
ACTUAL REDUCTION OF COST OF M LBS. STEAM
REDUCTION IN COST OF COAL PER M LBS. STEAM BASED ON $4.62½ PER TON
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR.
1916
1917

FIG. 80.—INCREASED EFFICIENCY AND REDUCED UNIT COST

The record of improvement of operating and managerial practice in this plant is illustrative. If the coal were purchased all the time at $8.35 the reduction in cost of steam was 44%; if the price of coal were constant at $4.62½, the bottom curve shows the reduction. With the price of coal gradually increasing the actual cost of steam per M lbs. was reduced very materially, same as in the case in Fig. 79.

In this case the average boiler efficiency as established by an eighty-day observation of hand-fired Edgemoor boilers was 54 per cent. Without any expense for improvement or additions to the generating equipment and with only a few additional instruments, the author's methods, comprising the task work with bonus, improved the average daily performance about 33 per cent.

The plant superintendent of this company, Mr. J. C. Scholl, above mentioned, makes the following statement: "The experiments were made at the Warrior Ridge power plant, where the firing is done by hand. Many tests were conducted to determine, not the greatest amount of coal or ashes that could be handled by a man in an hour or a day, but the amount that he could handle regularly, without fatigue. In addition the proper weight and shape of tools, the correct amount of material to be lifted each time, the least tiring

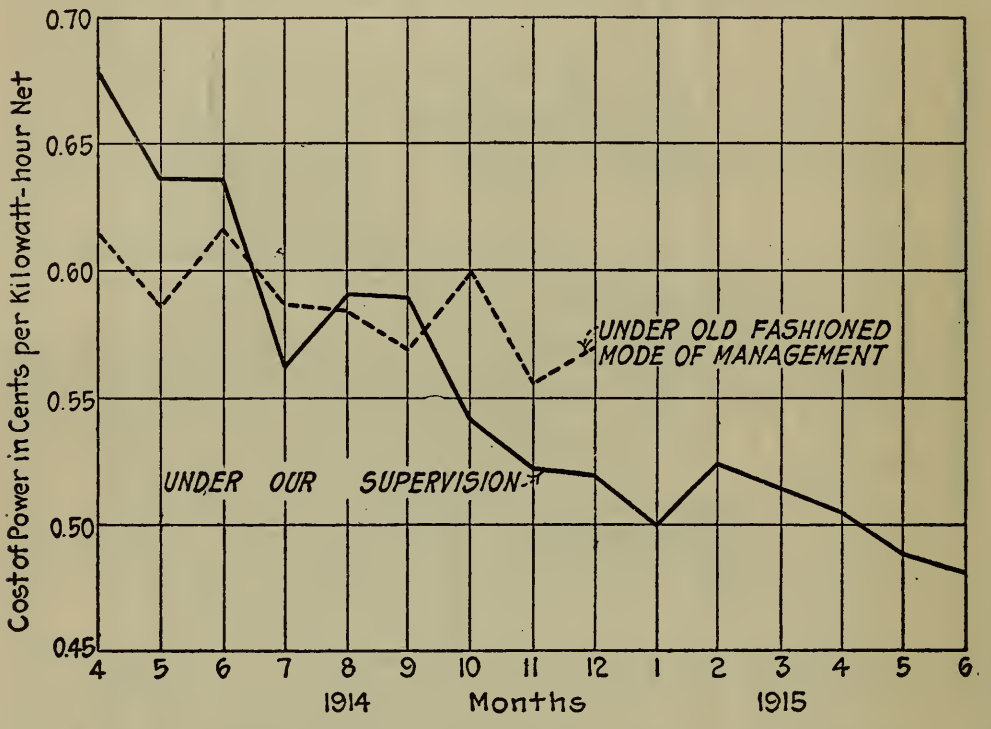


FIG. 81.—COMPARISON OF OPERATING COST TENDENCIES IN TWO RAILROAD ELECTRIC PLANTS

A railroad central station under an old-fashioned mode of management was able to operate more economically than another plant of neighboring railroad. The latter, desirous to reduce expenses, adopted in a measure our methods and in six months was operated decidedly more economically.

motions, the time required for each operation and the frequency of operations was determined.

"As soon as the best methods and equipment were determined, written instructions were prepared covering the practice that had been found to produce the best results, and the proper tools were provided. Instruments were installed that enabled each man to see that proper conditions were maintained.

"Then came the most difficult part of the task—the careful and patient drilling of each man in the correct performance of his task so that the same results would be secured the same way each time.

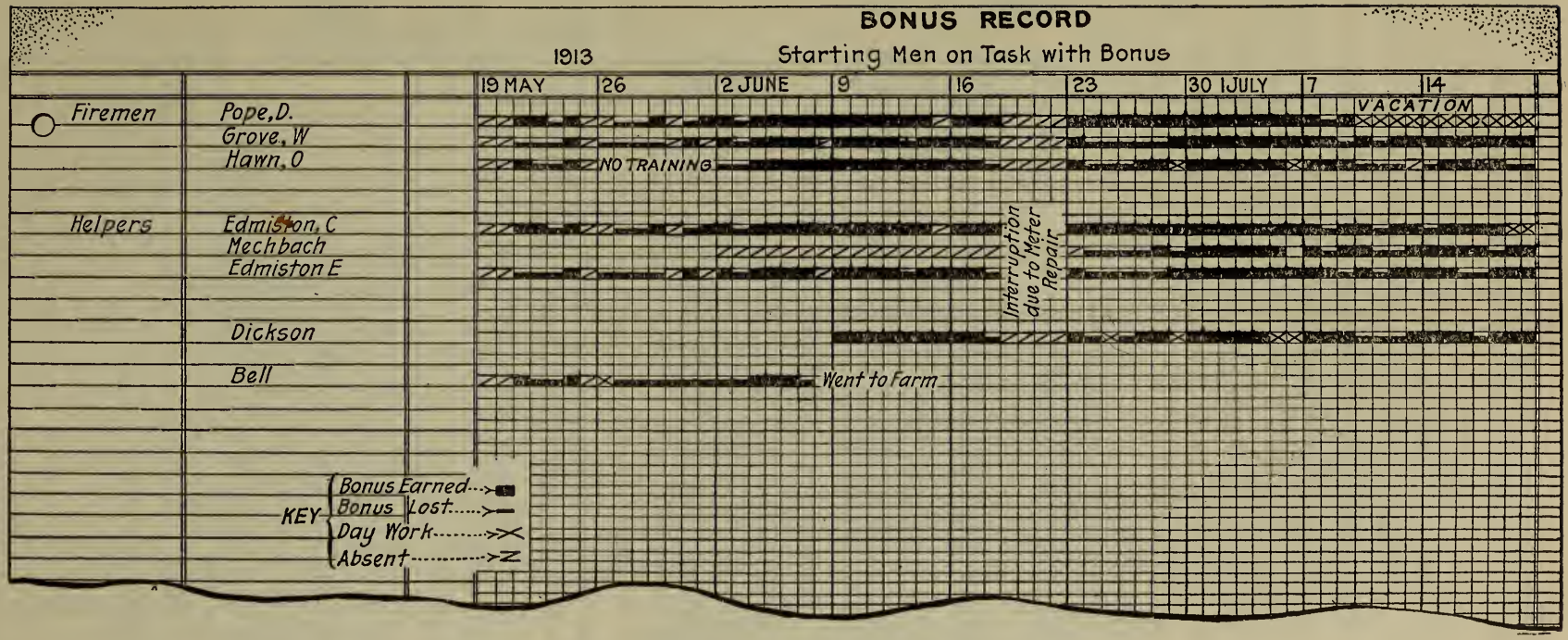


FIG. 82.—BONUS RECORD

The rapid progress in acquiring a new habit of industry and earning secondary rate by crew in a small public utility plant was partly due to preliminary period of investigations and studies during which men received careful instructions.

The success of such training depends to so great an extent upon the willingness and the sustained interest of the worker that some plan had to be adopted for insuring this interest and coöperation. It was therefore decided to give each man a bonus for every day that he carried out the written instructions and attained or exceeded the results that should follow the fulfillment of the prescribed methods. The success of the plan is most gratifying, for not only has the company saved expense, but the workers have reaped benefits in higher wages and better physical condition after the day's work.

"The results obtained during ten average days at the Warrior Ridge plant under the system that has been described are shown in the following table:

RESULTS OF OPERATION FOR 10 AVERAGE DAYS

	Three Boilers
Heating Surface sq. ft.	6000
Horsepower, manufacturer's rating	600
Horsepower developed	1150
Horsepower developed above rating per cent	91.8
Maximum horsepower developed 15 minute peak, per cent	1500
Temperature of escaping gases, deg. fahr.	490
Temperature of superheated steam, deg. fahr.	505
CO_2 (approx.), per cent	10.5
Apparent evaporation, lb.	8.907
Equivalent evaporation, lb.	10.714
Factor of evaporation	1.203
Efficiency of boilers and grate, per cent	72.5
Steam per kw-hr., lb.	22.27
Coal per kw-hr., lb.	2.5
All-over efficiency, per cent	9.5
Cost per 1000 lbs. of steam, dollars	0.0823
Cost per kw-hr., of coal, dollars	0.00221
Average daily load factor, per cent	67.3
Pounds of coal banking per 1000 sq. ft. heating surface per hour	26.3
Coal used, kind	Broad Top
Fixed carbon, per cent	77.12
Volatile, per cent	15.95
Ash, per cent	6.93
Moisture, per cent	1.20
Heat Value, B. t. u.	14,350.

"The success of the system in use in our power plant is dependent upon a spirit of coöperation between the management and the workmen. *The management is compelled to accept its proper share of the responsibility and must keep in touch with the latest developments of boiler-room practice.* If any suggestions are adopted, an effort is made to give full credit to the originator of the idea. The workman's responsibility commences as soon as the standard has been established and is placed in proper form before him by the management."

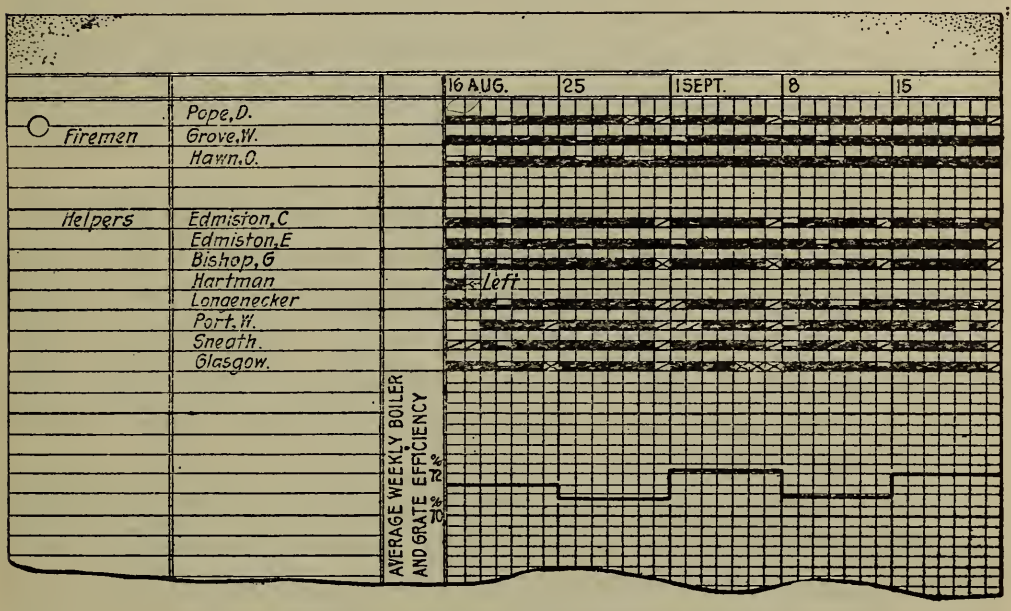


FIG. 83.—BONUS RECORD (*continued*)

In the same plant substantially the same crew continued to steadily earn a secondary rate and maintain a uniform high efficiency years afterwards.

In conclusion the author gives the following significant summary referring to the spirit created and maintained by practicing our principles of mastering power production:

"Not only have the results of the introduction of the new boiler room practice been most gratifying from the standpoint of reduction of expenses to the company and improvement in the conditions affecting the workman and his compensation, but it has also increased the mutual respect between management and workman and has developed the *esprit de corps* which is so beneficial to both. The workman is as much interested in the success of the methods and the standards which have been established as is the management. It is not the case of 'I' on the part of the workman, but 'We' are working together to obtain the highest efficiency in our boiler room."

This splendid spirit of democratic coöperation is the key-note of

the success of any industrial undertaking. Its attainment is based on that true leadership of men who know and who place their helpful knowledge at the service of men. It cannot be decreed from the central office; it cannot be instilled by absentee directors or maintained by an official who holds his job by bluff and who claims authority without assuming full responsibility for guiding, instructing, and helping the operating crew. Such service can be rendered only when based on the knowledge of facts and through men in industry it benefits the community it serves. The fostering of this "spirit of democratic coöperation" is finally the greatest result that comes from the work of the consulting management engineer in industry. Mr. L. P. Alford, concluding his article on "Results of Mastering Power Production" in May, 1920, issue of the *Industrial Management* said:

"To show the way in which this spirit works from below upward in improving power plant conditions the author of this article a few months ago walked with Mr. Polakov into the boiler room of one of his clients, The Celluloid Company. A firemen greeted us pleasantly and at once proceeded to tell Mr. Polakov that certain things were not right in connection with the plant and that he ought to have them fixed at once.

"The interest in improving conditions and mastering production revealed by this incident places in sharp contrast the differences between the mere improvement of machinery and equipment in a power plant and developing the 'spirit of democratic coöperation.'

"The logical way in which Mr. Polakov secures the results disclosed . . . is to search for a final, clear and definite answer to each of three fundamental questions:

1 Is the equipment of the plant doing its work?

2 Is the material utilized without waste?

3 Are the men properly trained and do they exercise their skill?

"The answers are made personal, being secured for every shift and are at once made known to everybody concerned. This arouses interest and if a suitable reward is offered for increased effort the employees take it upon themselves to secure the best possible results. This method arouses no opposition, for the improvements virtually originate with the men themselves and the work of the consultant is to advise the management how to help the men to do their best."

Chapter IX

MASTERING RECORDS

THE obvious object of power production is to replace physical exertion of human labor by application of some form of incarnate energy. The industrial evolution of the last century was characterized by an enormous increase of productivity of human society made possible by the use of mechanical and electrical energy as a motive power in production, transportation and communication. To record the progress in these activities is to record the advancement in generation and application of power.

If the labor of 100 miners, 30 railroad men, 15 mechanics, 5 power house men and 50 of various other occupations serving these people will produce enough power to save the physical labor of 200 mill workers, there would be no advantage to society to keep up mining, power generation, etc., for the same number of men in the same time could produce the same amount of goods working in the old-fashioned way without help of power machinery. The fact is, however, that about three millions of men engaged in various work contributing to power production help to produce more goods than thirty-six millions of men working twelve to fourteen hours a day could produce without the aid of power. In the words of Ex-Secretary of the Interior Franklin K. Lane "to know what we have and what we can do with it—and what we should not do with it also—is a policy of wisdom, a policy of lasting progress. And in furtherance of such a policy the first step is to know the resources —our national wealth in things and in their possibilities; the second step is to know their availability for the immediate use; the third step is to guard them against waste either through ignorance or wantonness; and the fourth step is to prolong their life. . . ."

These four steps toward the wise mastering of power production were analyzed in the preceding chapters; now our problem is to outline a method whereby we may learn the facts—*i. e.,* to measure the efficiency of mastering the problem which is second to none in the importance for the welfare and the future of society.

Purpose of Records

Any one but a feeble minded or criminally reckless person naturally wants to know the results of his acts. Even murderers are

known to eagerly read the accounts of their deeds and are very apt to visit the scene of the crime. The general absence of power plant records is however neither a surprise nor an exception for their absence is demanded by the impulse of shame.

It may be interesting to know that one year's coal consumption is equal in bulk to a Chinese Wall if erected to completely surround the United States and has, according to Steinmetz, enough potential energy to lift itself 200 miles high. It is shocking to admit that we irretrievably waste every year half of this enormous amount of fuel. In power production we utilize only about 7 per cent of the coal energy while with the existing, however imperfect, machinery we could make use of at least 10 per cent thus wasting 30 per cent through mere ignorance and indifference. There is nothing to boast about such records and so, in the past, little was known and still less said concerning our national pastime—daily coal destruction under boilers, in beehive ovens, in locomotives, at homes, on board ship, etc.

Under the pressure of war requirements however the startling revelations could not be any longer kept secret. Yet the publicity which this "Kultur" of our natural resources received was decidedly an unproved accusation as no accurate method of getting data of waste was available. Moreover, the method of analyzing the data obtained was not in general use. Records, however accurate and complete, are of no value unless they serve a definite purpose. To keep records merely for the sake of having them on file is worse than useless inasmuch as such practice requires labor, time and expenses, which might have been used more productively. *The true purpose of plant records is to direct the work of administration toward rendering maximum service with minimum waste.* To this end the records must show:

1 What is being done

2 How it is being done

Merely to know what *was done* is much less important than to know at all times what *is being done* and in the extreme cases records of the past do more harm than good. The more time elapses between the occurrence and the attention paid to the record, the greater is the amount of loss sustained in the meanwhile; the less therefore is the value of such belated record. Hence the first characteristic of records is that they must be *immediate.*

Another important consideration is continuity of record. Taking periodic readings on conditions subject to frequent or wide fluctuations cannot serve for the purpose of establishing fact, as periodic

readings may be taken during unrepresentative intervals, the conclusions thus becoming grossly misleading. Therefore the second characteristic of records is that they must be *continuous.*

Again, records of certain conditions or functions, however accurate and continuous, may be totally obscure or even misleading as to the results if these records in themselves are influenced by other conditions for which no proper accounting has been made. Therefore the records to be of full value must be *complete.* The paramount characteristic of a good record is of course its unquestionable accuracy, for only a *correct* record represents fact and gives information of value. Yet, records answering these fundamental requirements of being: (1) correct, (2) complete, (3) continuous, and (4) immediately available, occasionally prove of little value if they are not *clear.* Records that are difficult to read, interpret, and use because of their needless complexity, poor arrangement, obscure presentation and indefinite interrelation lose a major part of their value because neither a busy operator nor rushed executive can take the time and trouble to puzzle out the riddles of muddled records, and so they will keep on working as if they had no records at all or else use only a few of them that are easy to grasp. It may not be amiss, before we pass to classification of records, to illustrate by a few simple examples how the neglect of the above stated requirements of proper records renders them useless.

Incorrect records may easily mislead the men and the administration. A draft gage that got out of adjustment caused the fireman to maintain excessive draft with the result of large loss of fuel while bonus had to be paid him for correctly following instructions. In another case the management, basing their conclusions on the record of an automatic coal scale thought the boiler efficiency was near 70 per cent and for 9 months, until the coal storage was exhausted, neglected to do anything; yet the actual efficiency was 62 per cent because of an extra weight on the scale beam placed there by mistake and sealed by inspector. In the chapter on maintenance, due stress was laid on the importance of care of instruments and a method of periodic inspection and checking was briefly outlined.

Incomplete records similarly are often the cause of material losses. A boiler house of a large manufacturing concern where premiums were paid for high CO_2 content in flue gases had no means for keeping records of evaporation and boiler efficiency. After three years more complete records were instituted because of an alleged shortage of boiler capacity. It then became evident that with detached record of flue gas analysis 13 per cent CO_2 average corre-

sponded to 75 per cent of the load on the boilers running at about 60 per cent efficiency, while with 110 per cent average load carried with spare boilers and only 11 per cent CO_2 the efficiency was increased to 69 per cent average. In this manner 13,500 tons of coal were wasted annually due to incomplete records.

Intermittent recording likewise possesses elements of real danger to economy of operation. Half-hourly readings of electric load in amperes, recorded on the station log indicated apparently a large output for reasonable amount of fuel consumed and the plant operation was continued in happy ignorance for years until a graphic watthour meter was borrowed. It showed that nine pounds of coal were used per kilowatt hour and the plant was promptly discontinued and electric energy purchased from a near-by hydroelectric plant at a price that would mean a loss if compared with the old ampere record but which in reality meant a comfortable saving of fuel and money. A record of a large public utility boiler-house in Philadelphia apparently indicated that an average ashpit pressure maintained there was about two and a half inches of water. When an attempt was made to see this pressure continually kept, it was found that the fan would be shut down for three minutes approximately every seven minutes. Yet their combustion engineer regarded it as bad form to take down the record while the "jack was down," recording only the reading at nearly full speed of the fan. It is easy to imagine how much coal was wasted in this case both due to banked fires and escaped volatile combustible matters during these three minutes, as well as due to excess of air during the seven preceding ones. The loss was sustained "coming and going," but the record showed a uniformity.

Delayed records, not immediately available for guidance and control are similarly limited in value. In a middle western plant an elaborate array of recording instruments was installed in the chief engineer's office. Once a day the readings would be taken out, calculated and filed away. The operating men were totally blind as to what they were doing. The results were not satisfactory and the "boss" was displeased. But the men, feeling that they were unjustly criticized did not care to stand the abuse and shut the plant by a walkout.

In another case the fairly complete and accurate records were not analyzed until Saturday afternoon and the men notified as to their results on Monday. Obviously an error made in adjusting the conditions of the fire or distribution of load among the turbines could not be remembered and if changes were made, lumping daily

performances for a week together would not disclose what the change was for the better and what for the worse. The total thermodynamic efficiency of this plant varied between 6.5 to 7.1 per cent while the boilers could make 70 per cent and turbines 14 per cent efficiency on 24 hours variable load thus the loss in this plant was nearly (9.80—6.75)6.75=30.3 per cent.

Records that are *not clear* or comprehensive require more than ordinary effort for interpretation and generally fail to render useful service. Complicated charts upon which several recording pens are drawing a web of multicolored lines on different scales, etc., are seldom used by men as a guide for their work. Even in the office these charts are generally looked upon with amazement if not bewilderment and only a few trained persons can read their hierogliphic signs. Similarly purely engineering records, thermodynamic diagrams on logarithmic paper, etc., excite more admiration (or jokes) in the main office than they serve as incentives for help, coöperation and recognition of work done and handicaps encountered.

The purpose of records being representation of what is being done, the keeping of records merely means to present the facts for the use of operators and executives. When the facts pertaining to the actual performance are known, it is possible to compare it with the ideal or practical task and to thus judge the degree of perfection. Indeed records which do not compare *what is* with what *should be* are merely dead letters, and hardly worth the paper on which they are written. The ultimate function of records is therefore to show immediately, clearly, correctly, completely, and continually:

1 Whether the loss occurs
2 Where it occurs
3 How it occurs
4 How big it is
5 How it is to be prevented
6 Who is to prevent it.

Classification of Records

The securing of accurate and instantly available records is therefore a basic condition for success in mastering production as well as distribution. Without a complete set of records, efficient generation of power is unthinkable but the possibilities offered by the keeping of records may be realized only on conditions that proper use is made of the story told.

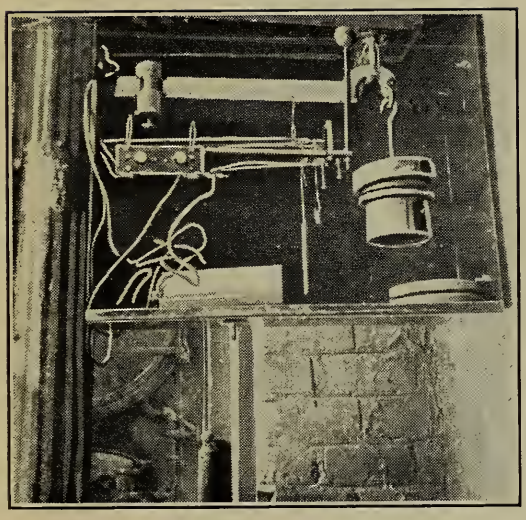
The mechanism for securing records must be organically fitted to the process under observation. Mere result of a performance leaves room for speculations and guesses as to its causes; thus ratio of pounds of coal per kilowatt hour constitutes neither a record of performance nor of the efficiency of equipment. In the first place three pounds of coal per kilowatt hour may represent 30,000 B. t. u. or 42,000 B. t. u. input. If we express the ratio in heat units per kilowatt hour, say 35,000 B. t. u. per kilowatt hour, we must know how many heat units are needed in a given plant under perfect condition of equipment and under proper method of operation before we know what the record means. If 28,000 B. t. u. per kilowatt hour is the practical aim to be attained, the record discloses 25 per cent loss, part of which may be due to poor maintenance and repair of equipment while another part may be caused by wrong operating practice. Again, kilowatt hours are born neither as Pallada from Zeus's head nor like Diana from a shell, ready made in all its divine beauty and glory; it is rather to be compared with a butterfly whose appearance in its final form is preceded by a long and tedious metamorphosis from an egg to a caterpillar, a chrysalid in a cocoon and only then she leaves Nature's womb to perform her brilliant feat. Likewise our kilowatt-hour passed several stages of transformation before it takes the form of electrical energy. The record, before it may be regarded as a useful information for elimination of this waste, must be able to allocate:

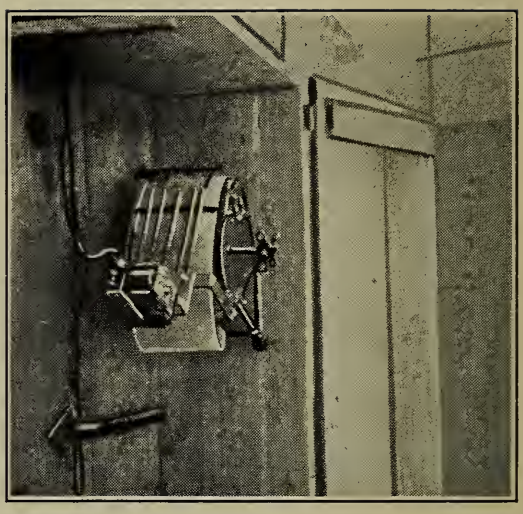
1 The stage in which the loss occurs

2 The cause of inefficiency.

Let us assume a steam-electric power plant, the inherent efficiency of principal units of equipment being for example as follows:

Stage	Efficiency, Per Cent	Process
Boiler plant, including all auxiliary	75	Transformation of thermo-chemical energy of fuel into volume energy of steam
Turbine room, including all piping and auxiliaries.....	15	Transformation of volume energy of steam into dynamic energy of shaft
Generating room, including excitation and transformation.....	80	Transformation of mechanical energy into electrical energy
Entire plant.....	9.	Entire process





FIGS. 84 and 85.—RECORDING ATTACHMENT TO A BEAM SCALE

A simple manner in which the coal brought to the boiler room can be correctly weighed and recorded consists in double electric contact which is closed when the beam is in balance. When the load is thus balanced two lights are lit and record may be punched on a tape besides the pen mark as shown in Fig. 86. Such home made recorder is cheap to make and answers the purpose.

The cumulative effect of losses is plainly apparent; they stand in dependent sequence to each preceding process since the loss sustained in a previous stage reduces the energy available for the following process. Only nine per cent of the heat energy available in the coal is finally transformed into electrical energy available on the outgoing feeders if this plant is operated perfectly; that is, if the equipment continually develops under operating conditions the maximum energy for which it is designed. This nine per cent represents 38,000 B. t. u. input to one kilowatt hour of plant output, which is theoretically equivalent to 3412 B. t. u. Neglecting the enormous waste of natural resources, caused by our crude and imperfect way of designing and building power-generating equipment, let us consider the effect of improperly using what we have. Suppose that our record actually shows that 48,750 B. t. u. in the shape of coal are used to generate one kilowatt hour. Comparing the actual performance with the possible task figure we find that our operating methods caused about 30 per cent loss. Now comes the question, where does this loss occur? If our record is complete, it would show a picture like this:

	Possible	Actual	Loss.
Boiler plant efficiency, per cent	75	56.50	24.66
Turbine room efficiency, per cent	15	14.00	6.66
Generating, transformation, etc., efficiency	80	79.00	1.26
All around plant efficiency, per cent	9	6.25	30.50

To analyze further the significance of these records, we must possess accurate information as to what causes the loss in each stage of the process.

The loss in steam generation may be produced by excessive or insufficient draft, poor attendance to the fuel bed, neglect to keep the heating surface clean, etc. The loss in the turbine room may be due either to a failure to apportion the load among different units so as to take advantage of the lowest region of the water-rate curve, or to neglected vacuum or to a poor condition of blading or even to poor attendance to the auxiliary mechanisms. Similarly, excessive electrical losses may be caused by factors that are just as much within the control of the management as the mentioned examples in boiler and turbine rooms.

Methods of Collecting Necessary Information

Observations recorded in handwriting. A large portion of data is obtained in this manner—store-room records, repair records, cost records and part of the data appearing on the operating log. Some of these data could not be otherwise obtained while others can be secured automatically with advantage. Weighing coal issued to firemen is seldom accurate if done manually and scales that require stamping a record are only slightly better than a coal passer's tally for he can just as readily forget to punch the scales as to move a peg on his tally-board or to mark a cross on his report slip. Platform scales are sometimes arranged to weigh only a fixed load, say 500 pounds, in a wheelbarrow balanced by adding or taking off coal. The record cannot be stamped unless the load is in balance, neither can the wheelbarrow be removed until correct weight is recorded. A sample of such a tape record and a photograph of the scale devised by the author, and used for the purpose, is shown in Figure 84 and Figure 85. In this case a mixture of bituminous and anthracite coal being used, the gates to coal bins and spouts are so arranged that the coal coming from one bin is recorded on one side of the tape while that coming from the other bin is shown on the opposite side. The correct load moved to the boiler room is marked by a burr on the corresponding side of the record line, and a hole automatically punched opposite denotes that the coal passer entered this weighing on his record. (See Figure 86.)

The efforts to substitute automatic records for manual ones are continually made and are generally speaking commendable with two important amplifications. First, instruments recording operating conditions, such as draft gages, ammeters, thermometers, etc., must be regularly read by operating men at frequent intervals and the readings recorded in writing on the log for they serve to *guide* and *protect* operation. The automatic record of the past, showing the cause of the burned armature or misused fuel may be interesting but it is not what is wanted, it is prevention of such occurrences that is sought and this can be assured only when the indications are constantly watched by operators. This practice has also a psychologic advantage as it provides interest in the work, stimulates attention, and schedules regulated trips for taking readings, during which other conditions may fall under operator's observation, etc. Secondly, nothing can be gained by automatic recording of individual man's performances. The use of census machines, etc., is warranted for sales records, account classifications, billing customers, etc., in cases

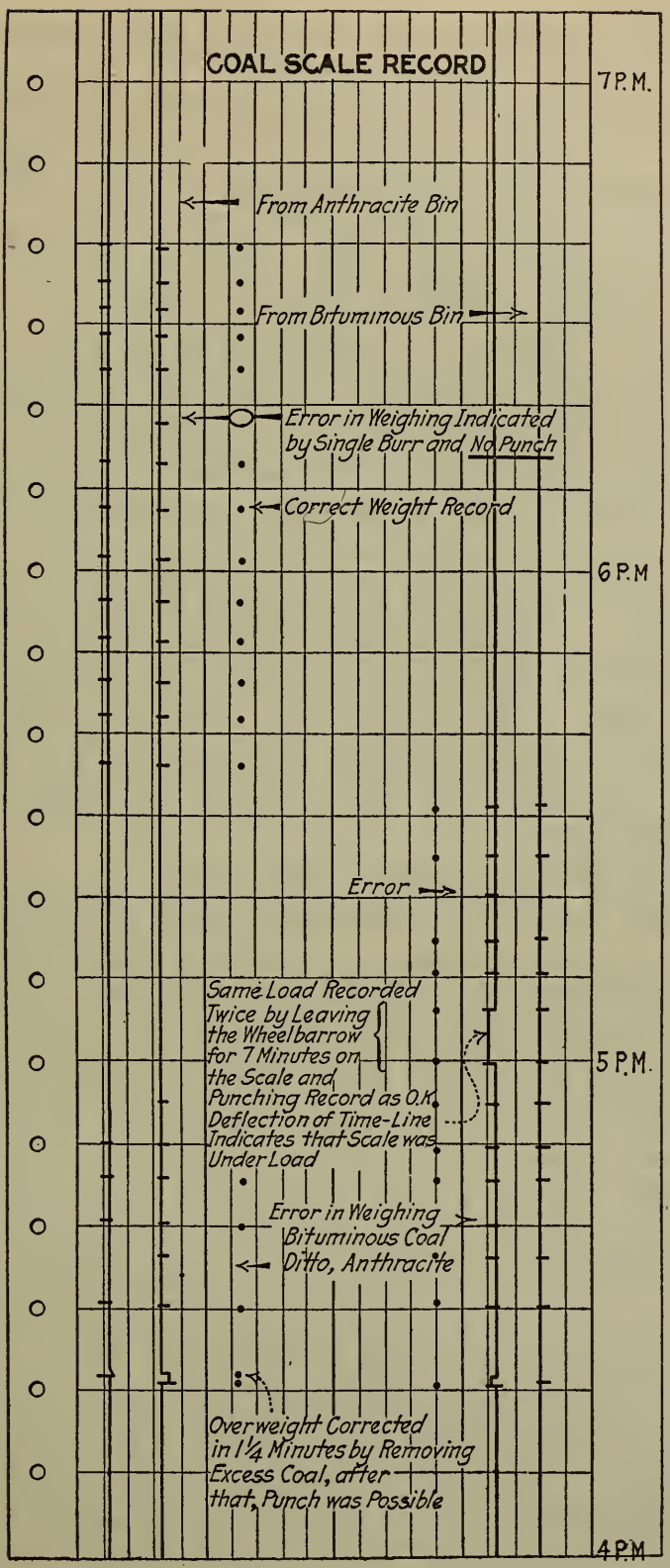

COAL SCALE RECORD
7 P.M.
From Anthracite Bin
From Bituminous Bin
Error in Weighing Indicated by Single Burr and No Punch
Correct Weight Record
6 P.M
Error
Same Load Recorded Twice by Leaving the Wheelbarrow for 7 Minutes on the Scale and Punching Record as O.K. Deflection of Time-Line Indicates that Scale was Under Load
5 P.M.
Error in Weighing Bituminous Coal
Ditto, Anthracite
Overweight Corrected in 1¼ Minutes by Removing Excess Coal, after that, Punch was Possible
4 P.M

FIG. 86.—RECORD OF COAL WEIGHED

Electric coal scale attachment as shown on photographs Figs. 84 and 85 gives above record. It registers coal passed from two bins. Two lines are from two contacts; burrs are made on both when load is in balance; only then punch mark is possible. For details see tezt.

where personal contact is less important than completeness and promptness of summarized informations. The cases of men's efficiency of work, amount of earning, reasons for failures, etc., must be closely and individually studied and scrutinized as otherwise gross misunderstanding and sometimes injustice is sure to follow.

Autographic records must have a widest application in power-plant work for they not only assure accuracy, but what is equally important represent a continuous picture of fluctuations the knowledge of which is essential and obtainable in no other way. Chart records of pressures, temperatures, voltage, watt-hour load, etc., are of great importance however only if the curves drawn by instruments are constantly before the eyes of operators; they lose most of the value if invisible or located in the office. The value of chart records for future studies of past occurrences is usually much exaggerated, for, in a well-conducted plant proper use of indications is made continually, while in a slip-shod managed plant a discovery that somebody did something wrong yesterday or last week is apt to bring no other result than a reprimand or a row. The cause of poor performance not being radically removed, its occurrence will repeat itself until either "the boss" will grow tired or men get irritated and utterly disheartened.

Integrating instrument records have their own wide application in power-house work and in many cases permit no substitution, such as integrating watthour meters, revolution or stroke counters, feed-water of steam-flow meters, time clocks, etc. Their function is to show total quantities, hence they cannot take the place of indicating or chart-drawing instruments which serve as continuous guides for operation. It is not enough to know however how many pounds of steam was evaporated, but the fireman should know at any time the load he carries; likewise it is not sufficient to know how many kilowatt hours were generated, but the operator should know constantly how the load fluctuates. Another very important useful function of integrating records is that of representing the amount of work done in a given period of time, serving two purposes—first: determination of schedule for cleanings, overhaulings, etc.; deterioration of efficiency, other conditions being equal, usually is proportionate to the output, not time. Second, determination of peak periods, necessary reserve capacity, fluctuation of demand throughout the twenty-four hours and the days of the week as well as for recording such conditions as fluctuation of voltage, shut downs, etc., which may be used to prove or disprove claims for damages.

Descriptive presentation of facts is usually the least satisfactory because it permits personal interpretation, modifications, and errors. It also requires more time to listen to the narrative or to read a report than to see figures and charts. In some instances, however, this is the only form in which the facts could be intelligently presented, particularly if the report is made to a person unfamiliar with technical details. For instance, whenever the conditions affecting the performance record were changed during or before the period reported a reference to such a change with explanations where and how it influenced the performance, should be made descriptive. In such cases the language must be clear and concise, arrangement of explanations parallel to numerical or graphical report and conclusions or corrections made for each item as well for final result; otherwise repetition and cross references cannot be avoided. Similarly, notes on the power-house log, remarks on requisitions, etc., constitute descriptive records and in all cases must be dated and timed. Date and time must be that of making the report or of the occurrence itself; *never* the date of transmitting them to the office. Typists should be instructed in writing reports never to date them with the date when they happen to transcribe same as this constitutes perjury and often puts the reporting party under unjust responsibility for delay, incompleteness, etc.

Numerical records, such as typified by tabulations, summaries, balance of stores, time tables, etc., should be avoided as far as possible, and substituted by diagrams and charts except when the exact numerical values are essential for these records or for the purpose of final graphic presentation. Hours of work, number of articles issued or received in store room, units of output, etc., constitute typical numerical reports this form being necessary in the first stage of working out the record but for permanent and comparative purposes they must be reduced to charts and curves.

Graphic records are the only convenient records inasmuch as they represent at a glance and usually with great accuracy and ease a number of facts that otherwise would remain obscure. The instrument charts, especially circular ones and those on variable scales, are not as clear as curves drawn on tape-charts with equally divided scales. More than one curve on instrument chart is seldom desirable; while for the purpose of comparison of interrelated functions multiple-pen charts have advantages in the office they are frequently confusing in the plant. It is always advisable to sacrifice the convenience of the office for the sake of helping operators to perform

better work; the office force handling these charts is trained and it is much easier for the supervising engineer to compare separate records at his convenience on the desk than for operating men to differentiate points of importance during the press of actual work. After the original or basic records are collected and worked out, in order to draw deductions and obtain the benefit of careful analysis of performance, the record data must be presented in a final form. Diagrams on two axes of coördinates, one of them usually being the time-scale, are very convenient for persons trained and could be easily adopted for study of relations of several factors. These diagrams may be either drawn or laid out on a display board by means of string or elastic stretched on pins as shown on Figure 87. Less often diagrams on three coördinates are used to represent more complex relations of factors recorded. Polar coördinates may be used to advantage in many cases but their usefulness is restricted to men with mathematical education being rather confusing for the operating force.

The common handicap of all diagrammatic representations is the use of two or more scales simultaneously, and as the object of graphic record is to picture the progress, amount, or quality of work performed in the plant the method must be so simple and obvious that any one could grasp its meaning without effort. Furthermore as regard men's records diagrams are bulky and irksome to use. It is hard to represent on a diagram more than the work of a few men and thus for comparison it is necessary to handle several diagrams carrying in memory the mental picture of each. On the other hand, a curve on one diagram representing an average of a group of men fails to give the individual's record which is of great importance. The method of presenting graphic records by means of straight bars obviates all the above difficulties and furthermore presents several other advantages.

Our central idea of records is that records must picture *what is occurring in the plant,* not *what has happened.* In this it differs radically from statistics which, as exemplified by the census, has a value for understanding the past and sometimes serve as a basis for prognostication of the future but never to master the present. Charts which continually show what progress is taking place in the plant, are sometimes compared with moving pictures, while tabulated data or diagrams of isolated phenomena are, like a photograph, detached from surroundings and devoid of means for comparative measurements. Furthermore, as it has been pointed out, our knowledge of facts receives its value only upon comparison of *what was done* with

what should have been done—call it as you may—a standard, an ideal, a task or a bogey. The charting method of presenting a living picture of progressive records is based on this standard accomplishment.

The time, the quality, or the quantity, expected or allotted for any process or performance is always the unit in our graphic method and this may be referred to a period, to a department, to a machine,

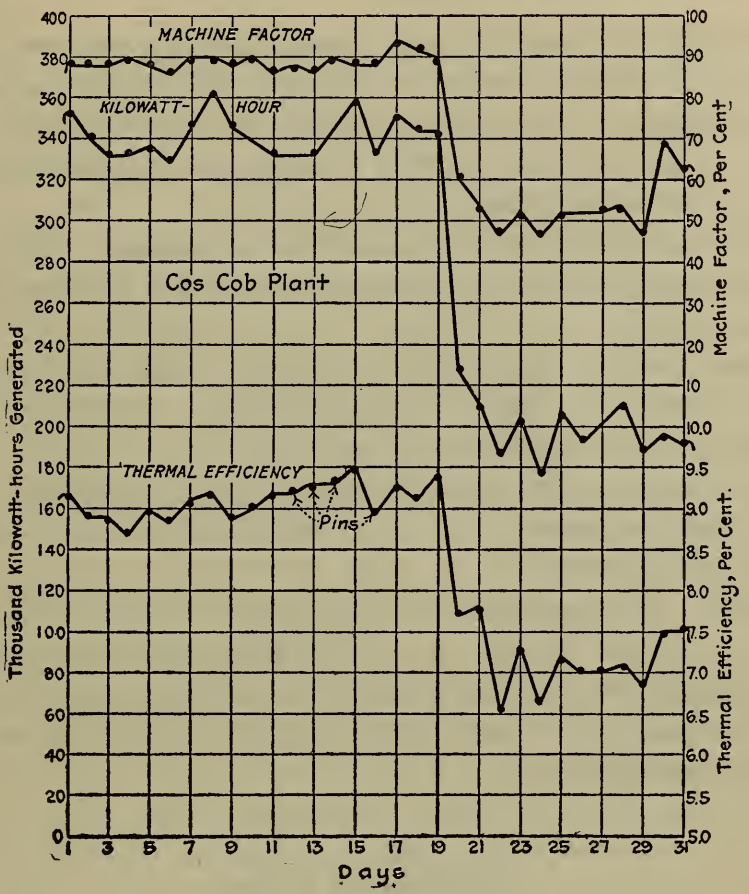


FIG. 87.—DISPLAY RECORD

In the chief engineer's office a board ruled as above is used to indicate fluctuations of load, machine factor, thermal efficiency of the plant, etc. Drop on 20th of the month is due to the beginning of parallel operation of RR. central station with a public utility plant selling power to the RR.

to an operator, or to several of these variables at once. Finally, this method, being simplified to a straight line in any and every case, not only permits quick and reliable comparison of as many as 292 items on one small chart, as for instance our Coal Utilization Chart, but allows accurate measurement of perfection of operations and above all is so obvious that every man in the plant or even in a bank* can readily understand the meaning and significance after brief explanation of the principle.

* The National City Bank, for instance, advocates these progress charts.

Function of Plant Records

The plant records should reflect three fundamental functions:

1 Whether the equipment is utilized

2 How the materials are utilized

3 What the men are doing.

Whenever any of these functions are not working properly we must know why in order to find the remedy. The most comprehensive way of finding out what is wrong with a plant and what remedy is needed is that of surveying the three charts representing working of these three principal factors:

Equipment in the plant is installed to be operated. The question to be answered is then: what portion of time it is being used and what does it do?

Material used in the plant is principally fuel that is converted into some form of energy. The question is: What portion of it is actually converted and what is wasted?

Men are in the plant to make proper use of equipment and materials. The question thus is: how well do they do it individually and if some fail, why?

If these performances of equipment, material, and men are charted in a simple manner by straight lines against the scale representing possible and desirable result, any shortcomings become apparent at a glance and proper efforts may be directed at once where the help is needed most.

Collecting Data

Time as a measure of work done has obviously no advantages except its simplicity, yet in a great majority of cases this simplicity is attained at a sacrifice of accuracy and fairness. While it is undeniably true that the time element is the most important factor in our life, that all thermodynamic processes and units of output contain time element or reduced to a unit of time like kilowatt hours, B. t. u. per hour, etc., and that time is perhaps the only thing that cannot be reclaimed and if wasted is lost irretrievably, *one hour's work* is an utterly meaningless term both as to the amount of work and the quality of it. Whenever we mention "hour of work" we must know definitely what is expected to be done during that time and what quality or efficiency of work or process is accepted as normal. A coal passer may deliver in one hour one ton of coal or

four tons; a fireman with one ton of coal can produce during one hour 10,000 or 20,000 pounds of steam.

Once we have established, however, the rate at which certain work is to be performed as well as defined the requirements as to its quality or efficiency, then the measurement of time receives its meaning, not in itself, but merely as a time-rate of certain performance.

So far as human labor is concerned, the time-measurement taken alone may serve only one purpose—as a basis on which the primary rate of wages (hourly or monthly pay) may be calculated. Yet one wonders how the productive time of a research man or of an executive could be measured or even ascertained, when the most valuable idea or plan was conceived while "resting in the movies" or even developed subconsciously while again weeks are spent at the desk or in the laboratory utterly fruitless of results.

On the other hand the measurement of productive time of machines is frequently neglected while it has indeed a well-defined meaning of great social and economic importance. One hour of idleness on the part of a 10,000 kilovolt-ampere generating unit represents, in fixed charges alone, a loss of nearly $25 and a many times larger loss of potential value of service not performed because of its idleness, while one hour idleness of its special crew would not amount to even $4.

The relative importance of keeping time of men's work is thus almost insignificant as compared with great value of time keeping of machines. For years the latter has been grossly underestimated and only meager data occasionally reported on the power log of which hardly ever any use was made. The question of expenses in connection with productive and idle time of machines and men is discussed in detail in the chapter on Analysis of Expenses and need not to be treated here.

Keeping Men's Time

The object of timekeeping from this broader viewpoint is:

1 To know who worked

2 To know when he worked

3 To know what he did

4 To know what he was paid for it.

Recording working time in a manner enabling us to answer these questions can best be accomplished by means of an ordinary

decimal stamp clock, printing time on a suitable time card, permitting necessary entries for calculation of bonus or secondary wage rate. For the purpose of facilitating the cost keeping these cards should be changed with every change of a job, thus there may be more than one card a day per man or the same card may be stamped repeatedly for as many days as the job lasts. This type is partic-

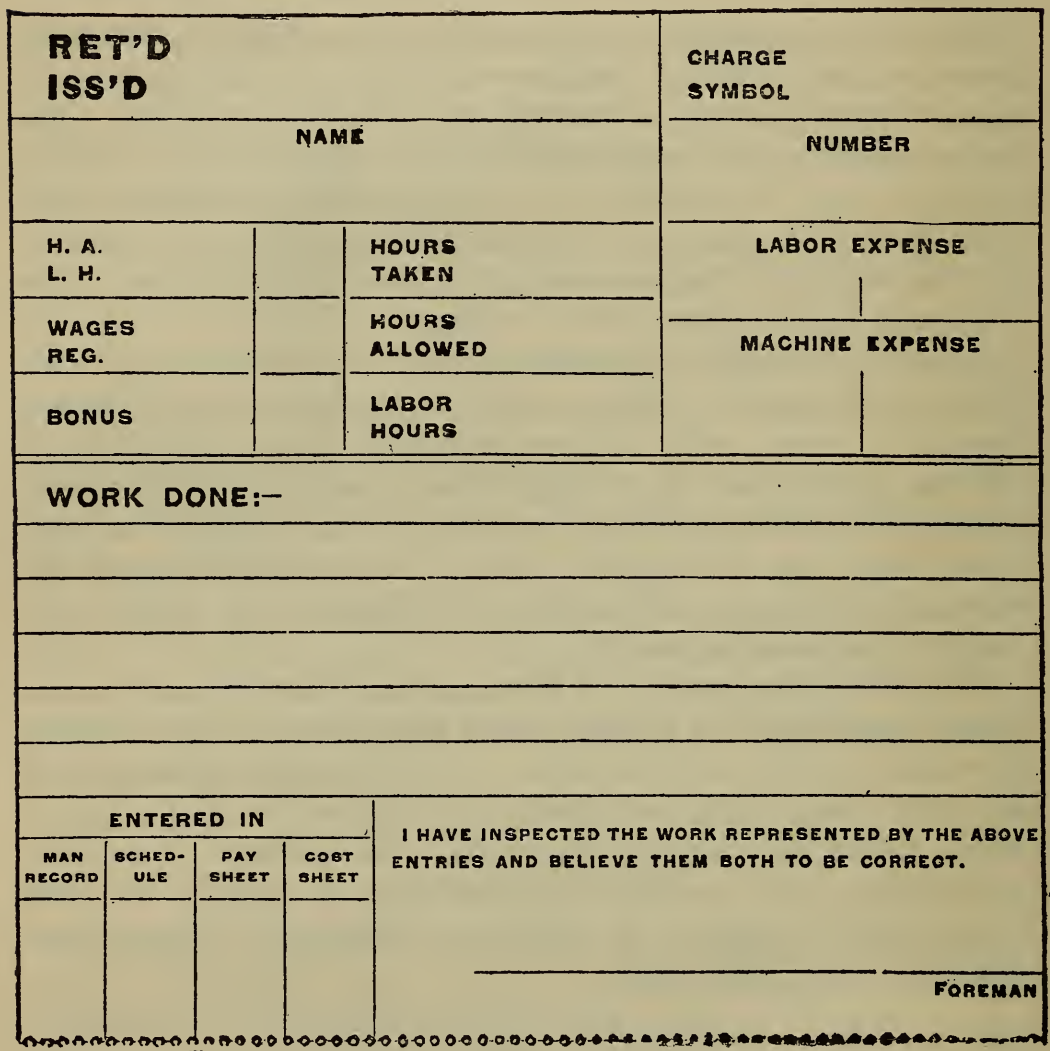


FIG. 88.—OLD AND NEW

International recording clock card may be used for repeated operation for (square) should be devised to meet the requirement.

ularly fitting for maintenance department, construction work, etc., where men are constantly shifted from one work or location to another. For keeping time of work that is substantially the same day in and day out, like switchboard operators, engineers, oilers, firemen, watchmen, etc., no inconvenience need be expected from the use of such even crude and inadequate records as those of old fashioned weekly "in" and "out" cards. (See Figure 88.)

In plants with a small crew all time-keeping records may be quite conveniently recorded directly on the log, while in the plants of manufacturing concerns the method existing in the shops may

WEEK ENDING .....19 ____
I. T. R. Co. Form No. 1212

No.
NAME

	MORNING IN	NOON OUT	NOON IN	NIGHT OUT	EXTRA IN	EXTRA OUT	
M							
T							
W							
T							
F							
S							
S							

TOTAL TIME.....HRS.

RATE.....

TOTAL WAGES FOR WEEK $.....

Styles of Time Cards

which no task is set and no special record is wanted. Otherwise a special form (Get any old international time card)

be adopted for the power house force, provided however, it offers the opportunity to:

1 Identify the jobs (by symbol or similar method)

2 Identify proper charge account

3 Differentiate between time rate earning (primary rate wage) and the quality rate earning (secondary rate or bonus).

Inasmuch as all jobs done in the plant may be classified according to the character of payment, the time cards must have suitable provisions for proper determination of the amount of wages due for any job whether it is paid by:

1 Hourly rate

2 Quantity task with bonus

3 Quality task with secondary rate.

Hourly Rate. This earning is a product of total time taken by hourly rate.

Quantity Task. In order to determine these earnings multiply the time allowed per piece, per ton or per any other unit of work by the number of units finished. If such time allowed (product of this multiplication) equals or exceeds the time actually taken, it indicates that the task has been made. The payment then is based not on the time taken but on time allowed plus a definite percent set for the job as bonus. If the time allowed is less than that taken, it indicates that the task was not made and the payment is based on straight hourly rate for the time actually taken. When quantity bonus is combined with quality, this is ascertained first, and the quantity bonus is paid if quality of work complies with requirement; otherwise only straight hourly wage is paid.

Quality Bonus. When quality of work constitutes the task, the quality or efficiency of operation is ascertained according to the established method. If the efficiency attained is equal or higher than that set as a task, the time actually taken is paid for at regular hourly rate as a primary rate of wages and on top of it an additional payment is made according to condition established for the secondary rate of payment.

These records of men's time collected on time cards are sent to the pay roll clerk after the chief engineer, superintendent or plant clerk has verified the correctness of time reported and the fact as to whether the task assigned was lived up to or not. As appears in the sample log reproduced in Figure 89 it is sometimes desirable to keep men's time recorded on the daily log with special marks denoting earning or missing the secondary rate of wages, nature of work done, etc.

Again it is always advisable to represent graphically on the man record chart or skill utilization chart, referred to in this chapter, the summary of use made of time by the members of crew.

FOR 24 HRS. BEGINNING AT 6 A.M.

MONTH	DAY	YEAR
June	22	1915

BOILER ROOM

IN SERVICE — BOILERS 1 2 3 4 5 6 7 8 — ECONOMIZER 1 2 3 4 — COAL CONVEYOR — COAL CRUSHER — HEATERS VB 113, VH 12, VH 24, VH 19 — STEAM PRESSURE — WATER IN OUT

FLUE GAS TEMPERATURES 1 2 3 4 5 6 7 SE SW

STEAM FLOW M. LBS. BOILER NUMBERS 1 2 3 4 5 6 7 8

HR	FLUE GAS 1	2	3	4	5	6	7	SE	SW	STEAM FLOW 1	2	3	4	5	6	7	8
6	410	500	415	490								110		35		45	
7	420	450	445	490								110		55		50	
8	410	450	455	465	340	250						119		145		137	
9	410	462	450	495								103		135		130	
10	415	470	450	495								102		135		116	
11	435	470	450	435								102		145		165	
12	430	460	445	415	340	250						113		80		90	
1	430	460	430	460								113		130		125	
2	425	410	455	430								113		145		130	
3	445	420	460	450								113		135		125	
4	460	450	460	460	330	300						111		120		125	
5	430	440	450	430								115		80		110	
6	440	430	440	440								113		60		70	
7	430	420	430	430								115		55		70	
8	430	410	410	420	320	290						115		60		90	
9	420	410	410	420								113		55		90	
10	424	420	400	415								112		95		75	
11	410	430	430	410								112		55		50	
12	400	430	350	410	250	260						112		75		0	
1	410	420	390	415								113		60		50	
2	430	460	400	415								113		75		30	
3	441	420	410	420								112		70		25	
4	440	420	420	430	360	295						112		70		0	
5	430	420	410	420								113		60		35	

Mixed Flues

TURBO GENERATORS — AMPERES 1 2 3 4 — VOLT — TEMP. MAIN BEARINGS 1 2 3 4

HR	AMPERES 1	2	3	4	VOLT	TEMP. MAIN BEARINGS 1	2	3	4
6	650				500				
7	525	450			"				
8	1440	700			"				
9	1460	850			"				
10	1500	900			"				
11	1440	750			"				
12	1200	550			"				
1	1400	650			"				
2	1460	650			"				
3	1460	600			"				
4	1460	580			"				
5	1340	400			"				
6	960				"				
7	900				"				
8	880				"				
9	900				"				
10	900				"				
11	880				"				
12	860				"				
1	860				"				
2	880				"				
3	840				"				
4	840				"				
5	700				"				

ENGINE ROOM

D.C. GENERATORS — YG 15 AMP. — YG 16 AMPS — VOLT

TRANSFORMER C° — BANK 40 KW. 1 2 3 — BANK 25 KW. 1 2 3

IN SERVICE — AIR COMP. 1 2 3 — ICE MACH. 1 2 3 4 — PUMPS: HYDRAULIC VH 10, VH 20 — FEED VH 80, VB 17, VB 18 — CONDENSER VB 110, VG 14, VB 24, VG 34, VG 19, VG 12 — WATER VHW 11, VHW 21, VHW 22, VW 2, VW 23 — COOLING TOWER DRAUGHT N. F.

HR	D.C. YG 15 AMP.	YG 16 AMPS	VOLT	TRANSFORMER C° 40 KW. 1	2	3	25 KW. 1	2	3	AIR COMP. 1	2	3	ICE MACH. 1	2	3	4
6		10	260													
7		30	"													
8		50	"													
9		70	"													
10		150	"													
11		60	"													
12		30	"													
1		45	"													
2		60	"													
3		60	"													
4		60	"													
5		60	"													
6		30	"													
7		30	"													
8		60	"													
9		40	"													
10		90	"													
11		40	"													
12		20	"													
1		20	"													
2		20	"													
3		30	"													
4		20	"													
5		20	"													

STEAM FLOW METER RECORD. TOTAL

	SHIFT	END OF RUN	START OF RUN	DIFFERENCE	TOTAL
METER NO. 1	1	935	930.6	5.4	102 904
	2	942.5	935	7.5	91 550
	3	946	942.8	3.2	61 033
METER NO. 2	1	521	514.2	6.8	262 806
	2	527.4	521	6.4	247 347
	3	531	527.4	4.4	170 051
TOTAL STEAM GENERATED					933 181
MANUFACTURING LINE	1	2941	2532	116	55 860
	2	3064	2945	116	55 860
	3	3155	3064	91	67 340
					239 020

TURBO CONDENSER RECORD

SHIFTS	1 TEMP.	1 VAC.	2 TEMP.	2 VAC.	3 TEMP.	3 VAC.	4 TEMP.	4 VAC.	INTAKE TEMP.	BARO-METER
8-AM					27					
12-AM					25					
4-PM					24½					
8-AM	27									
12-PM	27½									
4-AM	25									

WATER METER NO. 1 HOUSE

SHIFT	LAST READING	PREV. READING	DIFF.
1	596030	585010	10020
2	597650	596030	9620
3	605756	597650	8110

WATER METER NO. 2 DAMPER

1	51360	51326	034
2	51410	51360	50
3	51410	51410	000

WATER METER NO. 3 HYDRAULIC

1	201760	201392	368
2	201804	201760	392
3	201876	201804	032

WATER METER NO. 4 RETURN

1			
2			
3			

WATER METER NO. 5 HEATER.

1			
2			
3			

WATT METER NO. 1

1	5119375	5110200	9175
2	5126500	5119375	7125
3	5130950	5126500	4450

WATT METER NO. 2

1	6162375	6149450	1325
2	6176100	6162375	1375
3	6185350	6176100	1250

WATT METER M.G. SET

1	6137	5926	211
2	6349	6139	210
3	6555	6347	208

REVOLUTION COUNTERS

SHIFTS	AIR COMP. VA. 1	2	3
2-PM.			
6-AM.			
DIFF.			
10-PM.			
2-PM			
DIFF.			
6-AM			
10-PM			
DIFF.			

SHIFTS	ICE MACHINES YR. 1	2	3	4
2-PM.				
6-AM.				
DIFF.				
10-PM.				
2-PM				
DIFF.				
6-AM				
10-PM				
DIFF.				

PUMPS	VH-10	VH-20	VH-30	VW-2	VW-23	VF-1
2-PM.						
6-AM.						
DIFF.						
10-PM.						
2-PM						
DIFF.						
6-AM						
10-PM						
DIFF.						

BOILER ROOM CREW

NAME	JOB	BONUS ON SHIFT 1	2	3
—	Fireman			
—	"			
—	"			
—	Helper			
—	"			
—	"			
—	"			
—	"			

BOILER ROOM REPAIRS

NAME	IMP.	REPAIRS	ORDER NO.
John Doe		Stoke tagme	110MG-3
			327

ENGINE ROOM REPAIRS

NAME	INSP.	REPAIRS	ORDER NO
N. Baumann	V	Ice Machine	HOMP-1

COAL STATEMENT

CAR NO.	R.R. NO.	TIME RECEIVED	UNLOADED	GRILL OUT	REPORT OF COAL UNLOADED TODAY

NAME	JOB	BONUS 1	2	3
D. Gould	L			
W. Doe	L			
M. Morris	L			
N. Peters	L			
L. Moore	L			
J. James	C			
Ackerman	L			
Doyle	L			
Moulton	L			

TOTAL NEW DELIVERY	None —
UNLOADED IN 24 HOURS	—
PREVIOUS BALANCE	3813.22
TOTAL AVAILABLE	3813.22
TAKEN TO: BBO	—
TAKEN TO: REFINERY	—
TAKEN TO: BRUSH & COMB	455
USED IN POWER PLANT	5378
TOTAL ISSUED	5833
BALANCE ON HAND AT 6 A.M.	3760.89

SUMMARY

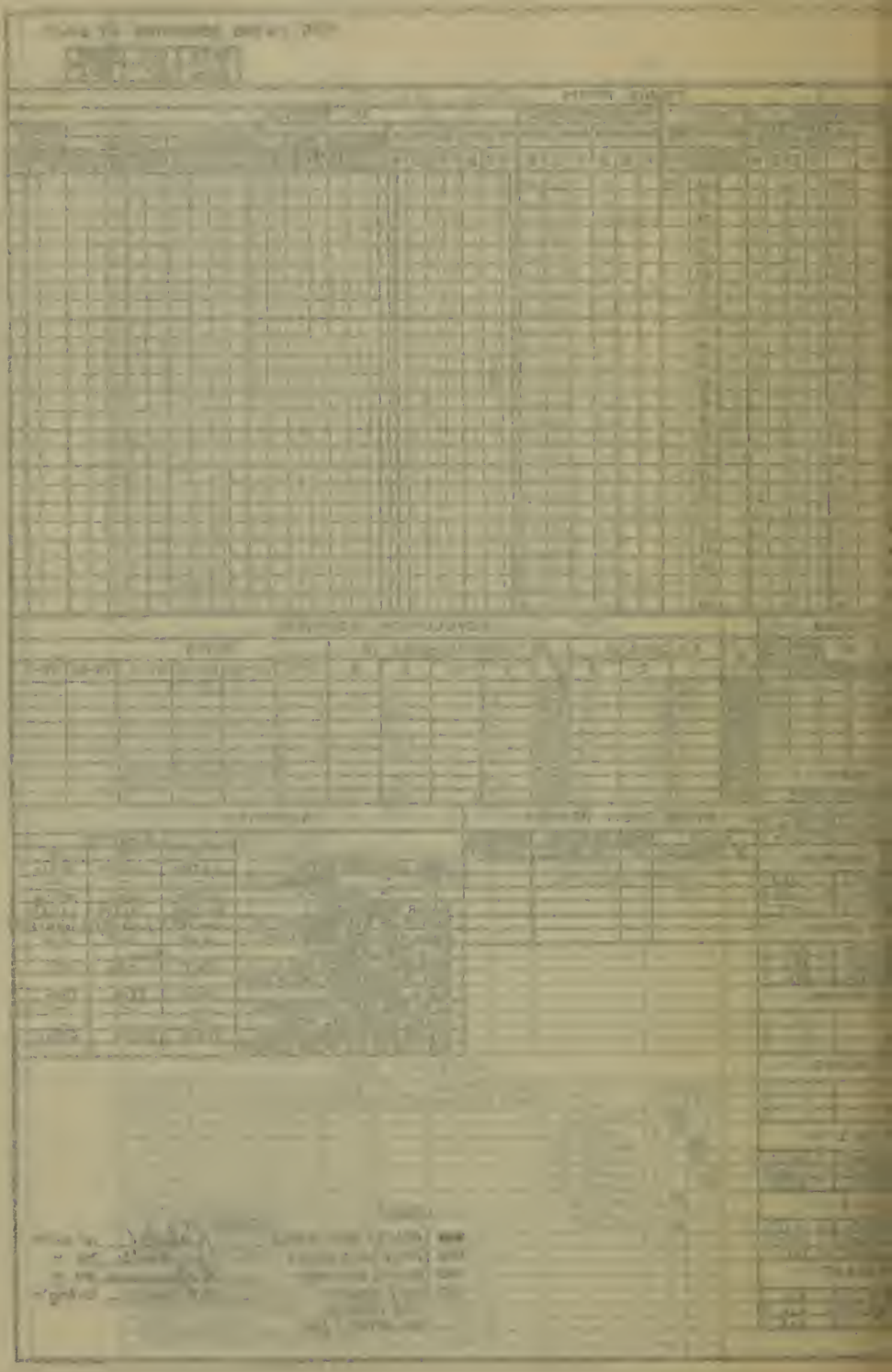
	SHIFTS 1	2	3
COAL CONSUMED TOTAL	373.0	344.0	154.0
" " BANKING	—	—	—
" " IN P.H.	373.0	344.0	154.0
WATER EVAPORATED	865 00	337137	210 CU
FACTOR OF EVAPORATION	1006 10.5	1011 10.5	1014 10.5
EQUIV. EVAP. PER LB. OF COAL	10.5	10.5	6.74
B.T.U. PER LB. OF COAL		11000	
EFFICIENCY OF BOILERS	72.5	74.2	71.3
COST OF COAL PER M LBS OF STEAM			
K.W.H. GENERATED	140 Em	134 En	1500
CU. FT. FREE AIR COMPRESSED	—	—	—
FT. LBS. HYDRAULIC WORK	—	—	—
STEAM FOR MANUFACTURING	1614	1134.0	617.0
PER CENT OF IDLE PLANT CAPACITY			

LEGEND
- (BLACK) MADE BONUS
- (RED) LAST BONUS
- (BLACK) DAY WORK
- (RED) ABSENT
- TIME RUNNING
- RUN WITHOUT LOAD

SIGNED.
Schubel 1st Shift
Jos Knoll 2nd "
N. Baumann 3rd "
W. P. Quipple Ch. Eng'r.

FIG. 89.—SPECIMEN OF A POWER PLANT LOG

Reproduction of an actual log showing the performance of crew and earning of secondary rate of wages.



Keeping Machines' Time

The keeping of machines' time is relatively much more important than keeping men's time. According to the central station census of 1912 the division of expenses for men and machines was as follows:

	Per Year	Per Hour
All salaries and wages	$61,161,941	$6,982
Fixed charges on plants	$88,547,983	$10,108

Assuming that all men worked 8 hours a day 365 days per year, the average hourly earning was 26.5 cents per employee (including higher paid officials), while fixed charges per establishment per hour were $1.94. As averages of this kind are necessarily confusing, due to combination of widely varying extremities, both as to employee earnings and character and size of plants, two specific examples may elucidate the point in question. A 32,000 K.V.A. plant of an electric railroad bears hourly fixed charges of $29.76 while total hourly pay roll in 1914 was $14.22. In a typical factory power house (3,600 boiler horsepower) the fixed charges were $5.56 and the cumulative pay roll $5.11 per hour.

The significance of these figures is augmented by the fact that while the idle men's time cost but their wages, the idle time of plant equipment cost not only mere fixed charges, but incomparably more in lost earning capacity. The above referred to central station having one-third of its capacity constantly idle, if it could sell the current at 1.25 cents per kilowatt hour would have turned the loss of $260,000 a year due to idleness into a net income of $41,600.

The record of working and idle time of equipment should therefore be kept in every plant in a manner showing:

1 What units are working

2 When are they working

3 What are they producing

4 What it cost to keep them idle.

The questions are thus entirely comparable with those asked about men and the method of getting the answers suggests itself—time-keeping similar to that of men's work.

In the power station it is extremely simple to collect the necessary data. Any well designed and properly kept daily log has provisions for marking both the time every unit was in service and its output. In this manner we obtain answers to the first three of our

questions, while the fourth one can be answered by comparison of actual output with the full safe output for the given time. The percentage by which the actual output is short of that possible is the percentage of the fixed charges that represent the cost of having idle plant capacity above the necessary reserve for the safety. The presentation of these timekeeping data is explained in this chapter in connection with the equipment utilization charts.

Store Keeping

All materials and supplies used in the plant should be accounted for and record of materials should be collected and arranged so as to show:

1 What material was used

2 What quantity of it was used

3 For what purpose it was used

4 What did it cost.

All materials could be classified into four groups:

1 Operating materials such as converted or consumed in the process of power generation

2 Operating supplies such as do not take part in power generation or transformation but are necessary for running the plant

3 Maintenance materials such as used to maintain plant and equipment in best operating condition but not new additions

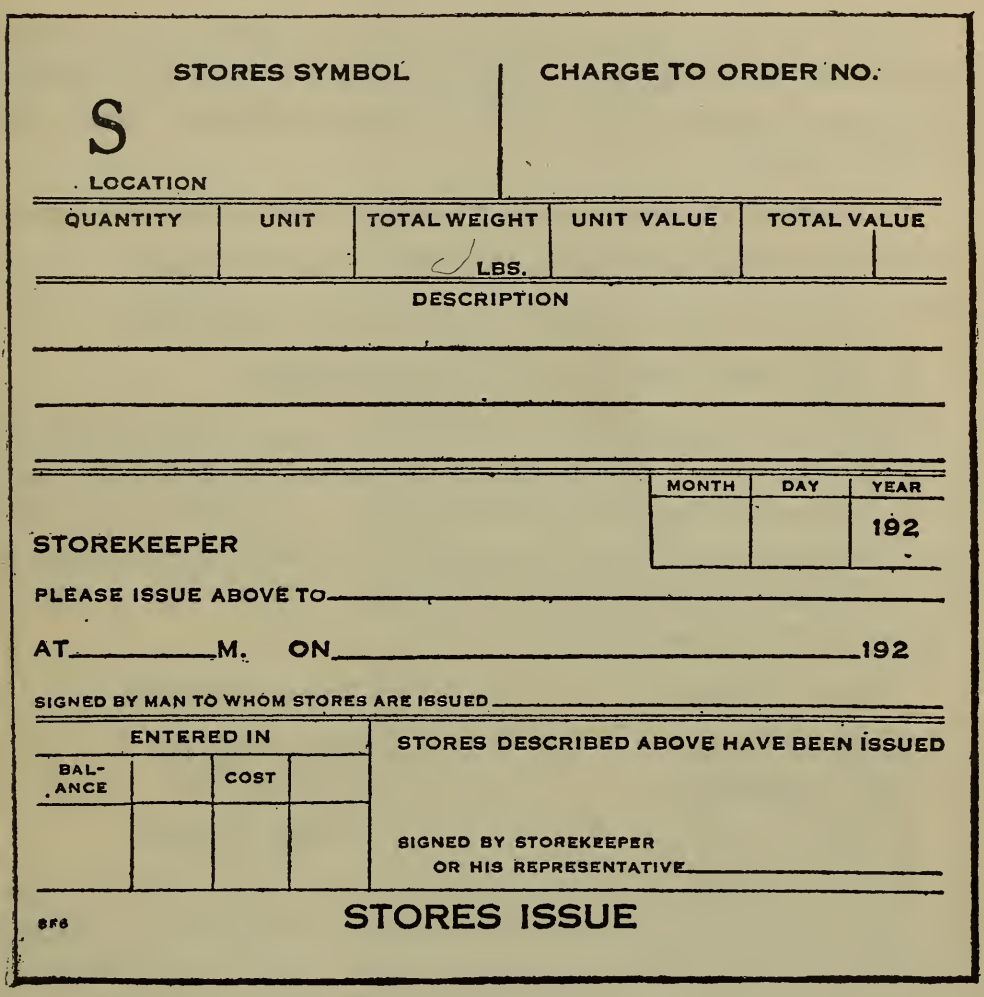
4 Second-hand materials and by-product.

In the chapter on Mastering Materials the routine of handling stores has been outlined. So far as operating and maintenance records are concerned we are here interested merely in collecting the data pertaining to store issues. Each and every article issued for use is covered by a store issue card (see Figure 90) which, when properly filled out gives all necessary information and thus serves as means of answering our four fundamental questions.

In a factory or mill power plant, if existing storekeeping practice is properly organized and correctly functioned, its stores issues could easily be made to serve the purpose by identifying each issue by the charge symbol. In very small isolated plants this matter

can be handled by operating engineers making adequate entries regarding materials used on the daily log.

Specific interests represent the collection of data on materials used for maintenance. While the results secured from the use of operating materials such as coal, are at once apparent from the


STORES SYMBOL

S

LOCATION

CHARGE TO ORDER NO.

QUANTITY	UNIT	TOTAL WEIGHT	UNIT VALUE	TOTAL VALUE
		LBS.		

DESCRIPTION

MONTH	DAY	YEAR
		192

STOREKEEPER

PLEASE ISSUE ABOVE TO

AT M. ON 192

SIGNED BY MAN TO WHOM STORES ARE ISSUED

ENTERED IN			
BAL-ANCE		COST	

STORES DESCRIBED ABOVE HAVE BEEN ISSUED

SIGNED BY STOREKEEPER OR HIS REPRESENTATIVE

8F6

STORES ISSUE

FIG. 90.—STORES ISSUE CARD

No material is issued from a store room without such issue card. These cards, properly filled out, when sorted give not only a check on stock of stores, but also represent a charge against the job or operation.

daily operating reports, the service rendered by maintenance materials cannot be accurately determined for a long time. It is obvious, therefore, that a mere record of store issue of such material is inadequate for correct judgment as to suitability or value of given kind, brand or quality. For this purpose all data pertaining to maintenance material are collected on special maintenance record cards (see Figures 44 and 45) referred to in the chapter on Mastering

Maintenance. In this manner we are able to know exactly what kind of material gives the most satisfactory service in the long run and what not, as well as to learn what method of upkeep or repair gives better results.

Operating Data

The collection of data recording operating conditions and methods is one of the most important routine functions of plant management. The principal questions that must be answered could be segregated into four groups:

1 How much energy and resources were consumer (input)

2 How much energy was delivered for use (output)

3 Under what conditions was operation performed

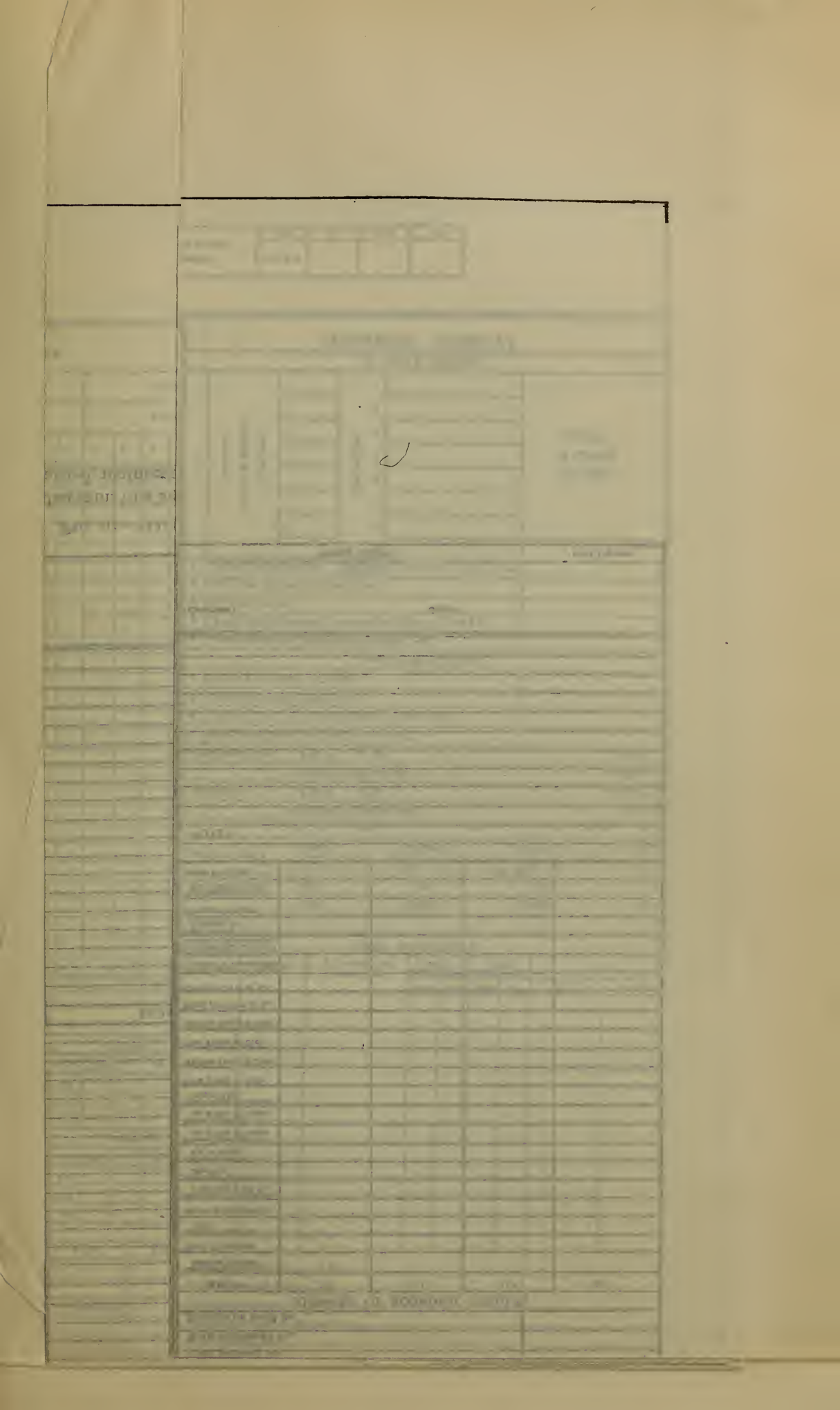
4 What were the results of these conditions

Inasmuch as operation is a *control of processes* the data should be so collected as to show clearly and distinctly what results were *due to control* and what results were *due to processes.* In other words an utmost care must be exercised to separate the influence of human factor on the natural phenomena. These factors may be roughly illustrated as follows:

Due to Men:	Due to Machines:
Unsuitable fuel	Poor design
Poor maintenance	Bad lay out
Unskilled work	Wrong purpose

For instance anthracite culm in furnace with weak draft will produce unsatisfactory results even if furnace and boiler are capable of good economy with suitable fuel while again poor design of baffles may cause a loss though furnace operation be perfect. Excessive soot and scale deposits will lower the efficiency of any boiler, while scattered boilers, unnecessarily long pipe lines, etc., similarly will increase expenses and waste. Lack of knowledge in distributing load or adjusting draft will cause very material loss, but such will be also the result of using perfectly good equipment designed for different purpose.

Obviously, the losses of the first class are under the control of management while the waste caused by the necessity of operating inherently inefficient plant should always be accounted separately. Common lack of appreciation of these dual causes of low efficiency in the majority of the plants is responsible in the popular tendency



FOR 24 HOURS ENDING | Hour | Day | Month | Year | 7.00 A.M.

BOILER ROOM

BOILERS: BABCOCK & WILCOX; HORNSBY & AKEROYD
ECONOMIZERS: Green; Sturtevant
FEED WATER PUMPS: B&W; H&B
DRAFT FANS: B&W; H&B
Blowers
DRAFT mm
TEMPERATURES °C: Boiler Room; City Water; Steam
Steam Pressure kg/cm²

TIME: 7 A.M. 8 9 10 11 Noon 1 2 1st Shift Average 3 4 5 6 7 8 9 10 2nd Shift Average 11 MN 1 2 3 4 5 6 3rd Shift Average

Stoker Engines 1 2 3 4 | Heaters 1 2 | Fire Pumps 1 2 | Service Pumps 1 2 | Coal Larries 1 2 3 4 | Air Locomotive

WATER METERS

		No. 1 6"	No. 2 12"	No. 3	No. 4
7	To-Day				
8	Yesterday				
	Difference	cu. ft.	cu. ft.	cu. ft.	cu. ft.

Boiler Room Crew

Title	7-3	B	3-11	B	11-7	B

Feed Water Temperatures °C

Watch		7-3	3-11	11-7
Before entering Economizer	S	°C	°C	°C
After leaving Economizer	S	°C	°C	°C
	G	°C	°C	°C

Coal Consumed kg

Watch	B & W BOILERS 1	2	H & B BOILERS 3	4
7-3				
3-11				
11-7				

Steam Consumed kg

7-3	
3-11	
11-7	

REMARKS

INSPECTION	REPAIRS	CMXS—
Boilers		
Economizers		
Feed Pumps		
Fan Engine		
Blowers		
Heaters		
Stokers		
Stoker Engines		
Shafting		
Piping and Valves		
Boiler Tubes		
Coal & Ash Equipment		

LEGEND: | Steaming or running. ≷ Banked. X In service. O Out of service.

TURBINE ROOM

PRESSURES KG/cm²: PRIMARY VALVE 1 2 3 4 5 6 7 8 | GOVERNOR OIL 1 2 3 4 5 6 7 8
TEMPERATURES °C: MAIN BEARINGS 1 2 3 4 5 6 7 8 | Room | Basement

Priming Pumps 1 2 | Air Compressors 1 2 3 | PUMPS Gravity Oil System 1 2 | SUMP PUMP

OIL ON HAND AT 7.00 A.M. BL: Turbine | Valve | Crank Case

Turbine Room Crew

Title	7-3	B	3-11	B	11-7	B

Average Vacua in Condensers

Watch	Barometer	1	2	3	4	5	6	7	8
7-3									
3-11									
11-7									

Temperature of Condensing Water °C

Watch	Tenths	DISCHARGE 1	2	3	4	5	6	7	8
7-3									
3-11									
11-7									

Tides

High	Time	Low	Time

REMARKS

Maintenance Crew

Title	7 A.M. 5 P.M.	B

Dummy Settings

No.	Tie	Bottom	Clearance	Date
1				
2				
3				
4				
5				
6				
7				
8				
11				
12				

REMARKS

INSPECTION	REPAIRS	CMXX—
Turbines		
Condensers		
Circulating Engines and Turbines		
Dry Vacuum Pumps		
Hot Well "		
Priming "		
Oil "		
Gravity Oil System		
Exciter Engines		
Piping and Valves		
Gauges & Instruments		
Heating System		

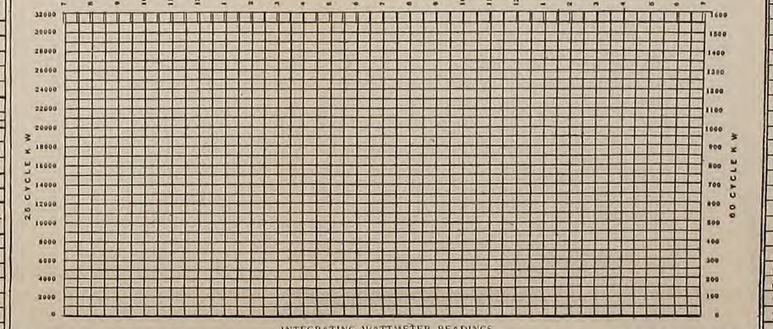
LEGEND: X In service. O Out of service.

SWITCHBOARD

GENERATOR K.W hr.: 25 CYCLES 1 2 3 4 5 6 7 8 | 60 CYCLES 11 12 13
OUTPUT K.W hr.: 25 Cycle | 60 Cycle | Total
EXCITERS: Steam | Motors — A B C S
TRANSFORMERS: Temperatures °C 1 2 3 4 5 6
FEEDERS: East | West — 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 — 3 Phase | Spare
Transformers Outside

TIME: 7 A.M. 8 9 10 11 Noon 1 2 3 4 5 6 7 8 Average

LOAD CURVE



INTEGRATING WATTMETER READINGS

	1	2	3	4	5	6	7	8	9	10	S.M	S.E	S.W
Today													
Yesterday													
Difference													

ELECTRICAL CREW

Title	7-3	B	3-11	B	11-3	B

REMARKS

LIGHTING ARRESTERS

F1-3W	⅄M	AN	⅄M	F1-3E	⅄M
F2-4W	⅄M	AS	⅄M	F2-4W	⅄M
T2-3W	⅄M	C1	⅄M	T2-3E	⅄M
T1-4W	⅄H	C2	⅄M	T1-4E	⅄M

Regulator Positions Changed: 1 2 3 4

Transformer Oil: Oil Balance | Gallons

Oil Balance: Received; Delivered; Used; Filtered; On Hand Clean; On Hand Dirty

INSPECTION	REPAIRS	CMXE—
Generators		
Exciters		
Motors		
Cir. Breakers		
Wiring		
Instruments		

LEGEND: | Running. ≷ Floating. X In service. O Out of service. C Charged. I Inspected. R Resistance in; Resistance out. G Ground. L Load dispatcher's resistance in. B Breaker out.

On Cross Section Chart Shows: Output in heavy black curve; Swings in heavy peak curve; Machine Cap. in dashed block curve.

Checked: _____ Chief Electrician.

ELECTRICAL SUMMARY

25 CYCLE SYSTEM

Generator Hours & Minutes in Service | GENERATOR 1 2 3 4 5 6 7 8 | TOTAL 25 CYCLE OUTPUT

2	Local Consumption	Meter N / Meter P
3	60 Cycle System Consumption	
4	3 Phase output	
5	Total Miscellaneous Consumption (Items 2+3+4)	
6	Total Railroad Consumption (Items 1-5)	

60 CYCLE SYSTEM

7	SIGNAL WEST OUTPUT	
8	SIGNAL EAST OUTPUT	
9	TOTAL 60 CYCLE OUTPUT (Item 7+8)	
10	GROSS PLANT OUTPUT (1+9-3)	
9	Maximum Hour ⅄M to ⅄M	KWhr
10	" " Machine Capacity Nos.	KW
Average	Minimum " ⅄M to ⅄M	KWhr
11	" " Machine Capacity Nos.	KW

	7-3 Time	KW	3-11 Time	KW	11-7 Time	KW
Maximum Swing		KVA		KVA		KVA
Machine Capacity	Nos.		Nos.		Nos.	
	Total	KW	Total	KW	Total	KW

Weather

COAL STATEMENT

CAR NO.	BARGE	H. R. or SHIP CO. Name of Coal	DATE DELIVERED Month	Day	DATE UNLOADED Month	Day	LBS. In Car or Barge	Unloaded

Total new delivery ____ in lbs.
Unloaded in 24 hours
Previous balance ____ in lbs.
On hand at 7.00 A.M. in lbs.
Used running lbs.
Used banking lbs.
Total consumed lbs.
Balance on hand lbs.

SUMMARY OF ECONOMIC RESULTS

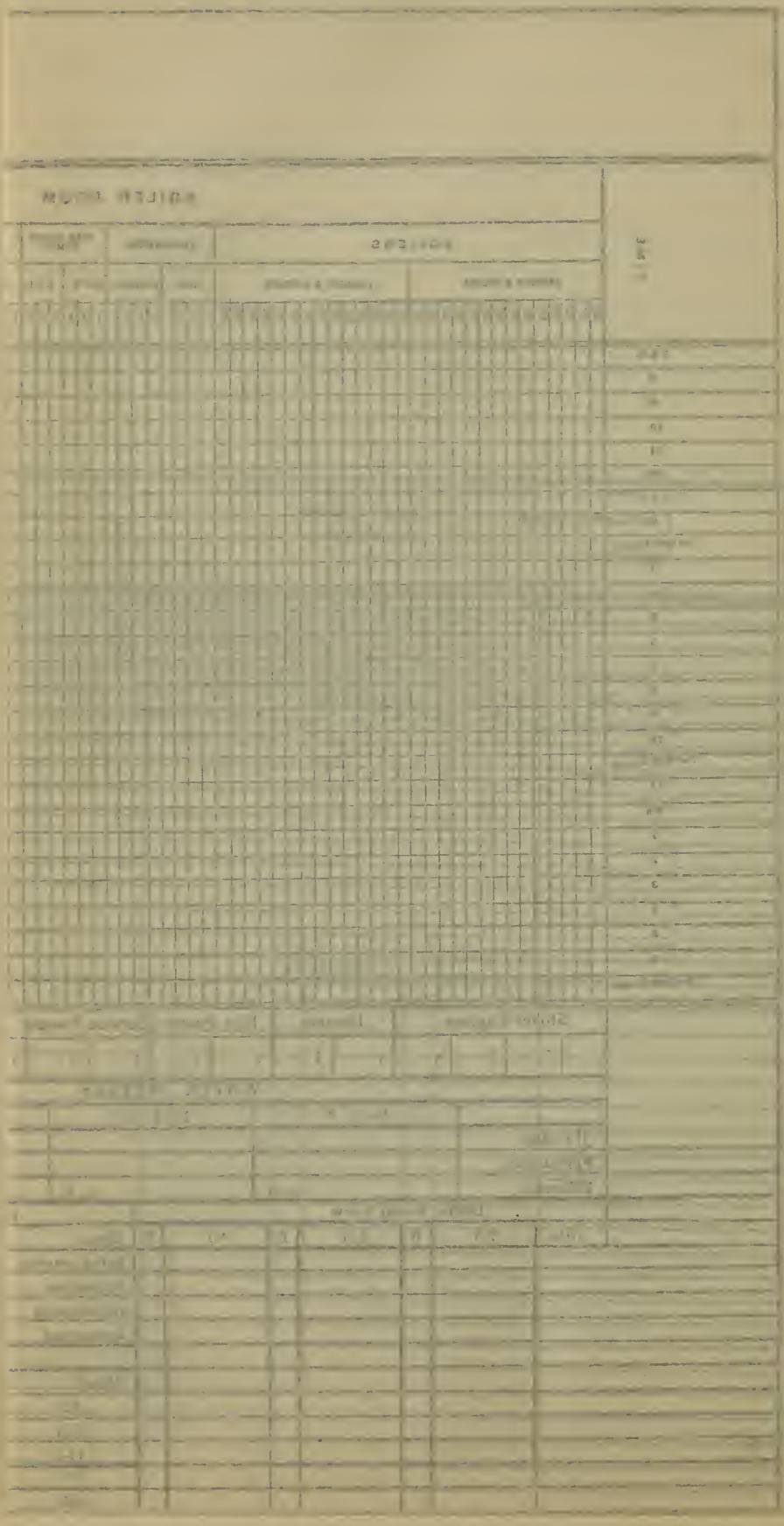
SHIFT	7-3	3-11	11-7	Day
Water fired in K.g. Banking excluded				
Water Evaporated				
Actual Evaporation Ratio				
Factor of Evaporation				
Equivalent Evaporation From and at 100 °C.				
Efficiency of Combustion %				
Cost of Fuel per 1000 Kg. of Steam				
Steam Generated Output KWhr 25 Cycles				
Steam Generated Output KWhr 60 Cycles				
Total Steam Generated Output KWhr				
Load Factor 25 Cycle				
Machine Factor 25 Cycle				
Load Factor 60 Cycle				
Machine Factor 60 Cycle				
Steam per KWhr in Kg.				
Coal per KWhr in Kg.				
Coal per Square Foot of Grate Surface per Hour				
Cor. coal for banking fire ____ Boiler ____ Hours per cent. or Grate Area Kg.				
Clear Ashpan Cinders # Kg.				
Thermal Efficiency				
Total Output entire station in 24 hrs. KWhr				
Water Purchased			Cub. Ft.	

NOTES

Checked: _____ Signed: _____
Planning Engineer. Chief Engineer.

FIG. 91.—DAILY LOG OF A CENTRAL STATION

Besides usual entries and a cross-section space for load diagram, this log, used by the author since 1914, contained a few pioneer peculiarities for that time, such as metric units (KWL, kgr, sec. C° etc.) performance of crew, bonus earned, maintenance and inspection entries, etc.



to excuse poor results by placing all blame on "old plant" instead of concentrating more efforts on improved operation of the existing equipment. Alterations and physical improvements introduced under such befogged impression seldom produce the expected measure of benefit, for the poor practice continues to fail to realize full advantage of new apparatus.

To the contrary, in some cases, blame is blindly put on the men and attempts are made to increase the efficiency by "calling the chief on the carpet" and browbeating the men instead of judiciously analyzing the losses due to plant itself and carefully estimating the extent of expenditures for modernizing the plant equipment warranted by the elimination of losses by such means.

On the other hand, the operating record data should be so collected and arranged as to permit differentiation of causes and results separately in each consecutive stage of the process of transformation of energy from fuel or penstock to busbar or driving shaft, etc. In a typical case of a carbo-electric plant at least three sequences of operating process must be segregated: (1) generation of steam; (2) generation of electricity; (3) transformation and distribution. This grouping usually coincides conveniently with three main departments of the plant: boiler house, turbine hall, switchboard and high-tension room. Frequently each of these departments is under the direction of a responsible head and differentiated records thus help to keep individual account of each section, while the analysis of operating details thus recorded is of great help to the respective heads to improve their methods and to intelligently coöperate with each other.

The daily performance log is no doubt the most important power plant record and its practical value depends as much upon its contents as on the manner in which it is filled. In course of our classification of methods of collecting and presenting data references were made to different modes in which the data appearing on the log may be secured. Whatever the means of making observations it is of the utmost importance that those actually performing the work or directing it should personally fill out the log or at least verify the entries at frequent and regular intervals. In this manner a seemingly perfunctory work of keeping station log accomplishes great deal more than collection of data—it becomes a foundation for real leadership inasmuch as it combines in one man *the inspector* and *the instructor*. A man constantly examining log-entries and comparing the progress and efficiency with records of conditions producing these results becomes an instructor and leader, for in every instance of

any deviation from good practice or in case of inconsistency of records he demonstrates to the operator, failing to maintain proper condition, how to do it and in this way helps him to secure better results.

Several samples of power plant daily logs are reproduced in Figures 89, 91, 92 and 93. These cover a wide variety of cases: a large central station of an electric railroad; a medium size public utility plant; two factory power plants, etc. The following instruction for log-keeping briefly outlines its object and routine.

OBJECT. The log is kept in the power house for the purpose of recording at frequent intervals as the work is progressing:

1 Conditions as affecting results
2 Equipment used
3 Time of occurrence
4 Men working (time and quality of work)
5 Materials used, received or issued
6 Results accomplished (amount and quality).

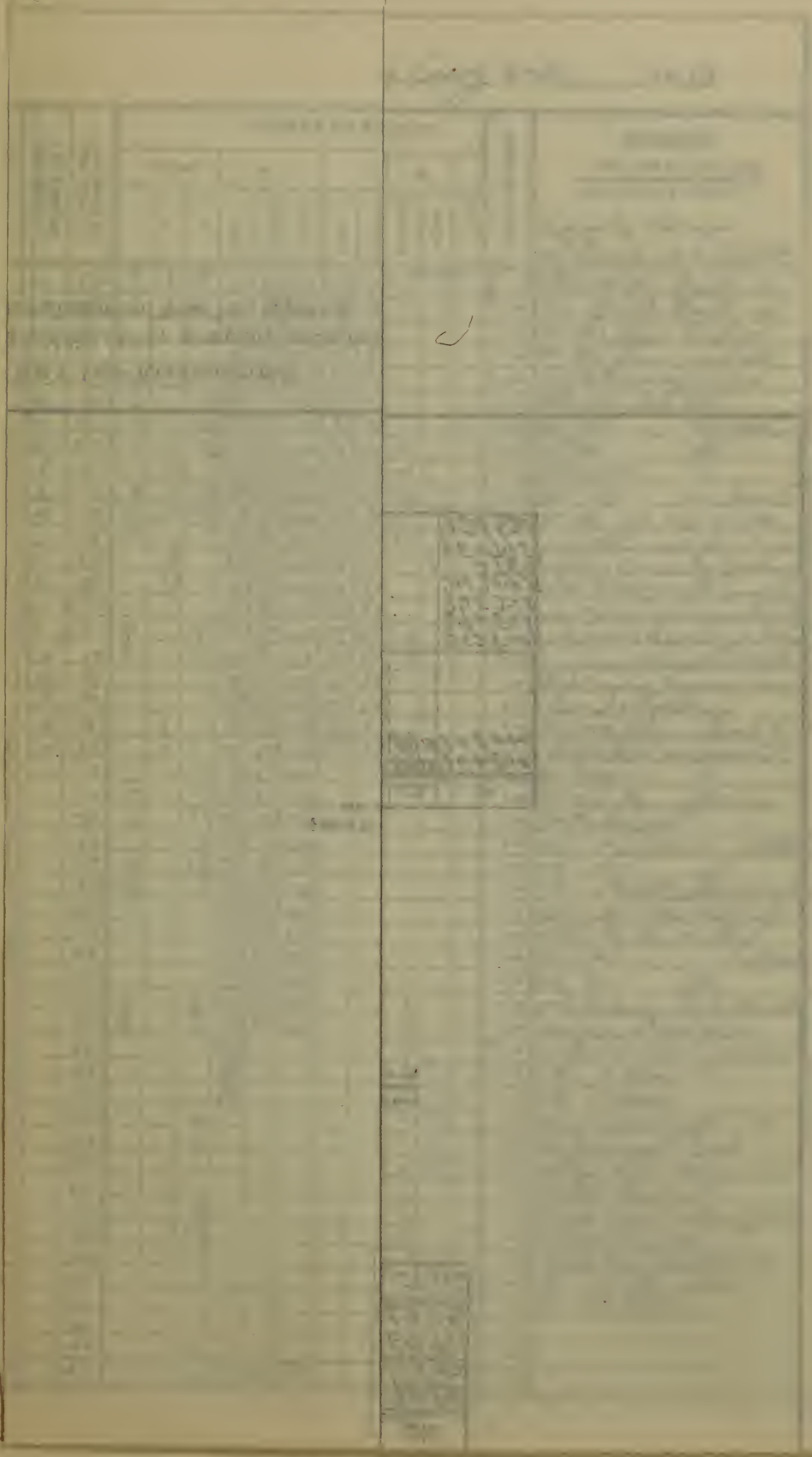
FORM. Log Form P 1 is kept in the boiler house, Form P 2 in the engine hall. When completed both are pasted together; the summary of results are made in duplicate copy being made on Form P 3.

KEEPING THE LOG. *Boiler Room Log P* 1 is kept by head fireman under supervision and responsibility of Boiler House Foreman. It is dated as 6 A. M. when started and returned to power house office at the end of 24 hours for computation. It registers:

Hourly
1 Units in use
2 Temperature of flue gases
3 Boiler load (steam flow per hour) each boiler
4 Draft, each boiler and furnace

Continually
5 Coal weights delivered to stokers (hard and soft)
6 Coal statement (coal cars received, unloaded, drilled out and sent to other plants)

At the end of each shift
7 Men working
8 Total coal (consumed, sifting, banking)
9 Signature of head fireman of the shift.



FOR 24 HOURS ENDING AT 7:00 A. M. Aug 2nd 1913

TIME OF READINGS	WATER LEVELS HEAD	WATER LEVELS TAIL	DIFFERENCE	WATER WHEEL GENERATORS 3 A	3 KW	4 A	4 KW	5 A	5 KW	6 A	6 KW	STEAM TURBINE GENERATORS 1 A	1 KW	2 A	2 KW	3 A	3 KW	TOTAL NO. KW.	EXCITERS WATER WHEEL 1 V	1 A	2 V	2 A	STEAM 3 V	3 A	TRANSFORMERS BANK A V	A	PF	BANK B V	A	PF	CYCLES	STORAGE BATTERY V	A	HDR	T
1:00	58.9	63.0	4.21			150	560					125	500	110	540	740	3300	3800	110	150	110	150			118	340	88	118	58	88	60				
2:00	58.5	63.6	5.02			120	440	140	560			100	400	100	360	720	2200	3500	100	170	100	170			118	370	93	118	700	93	60				
3:00	58.7	63.1	4.27					150	560			130	580	120	460	760	2300	3700	105	150	105	150			118	370	90	118	650	92	60				
4:00	58.7	63.1	4.27					150	560			140	540	130	520	760	2300	3700	105	150	105	150			118	370	90	118	650	90	60				
5:00	58.4	63.1	4.27					150	560			135	580	120	520	760	2300	3760	110	150	110	150			118	380	90	118	720	90	60				
6:00	58.6	63.3	4.73					150	560			135	580	125	580	780	2300	3950	110	150	110	150			118	380	90	118	720	90	60	113	15	1217	79
7:00	58.6	63.3	4.73					150	560			130	560	140	560	780	2300	4240	115	160	115	160			118	400	92	118	740	92	60				
8:00	58.5	63.1	4.62					150	560			135	560	140	560	780	2320	4000	110	150	110	150			118	370	93	118	700	93	60				
9:00	58.5	63.2	4.73					150	560			135	560	140	540	780	2400	4000	115	150	115	150			118	370	93	118	700	93	60				
10:00	58.5	63.1	4.73					140	540			140	560	125	500	720	2300	3720	100	150	100	150			118	390	91	118	700	91	60	113	15	1216	79
11:00	58.5	63.2	4.84					140	560			140	560	130	520	760	2300	3750	105	150	105	150			118	370	92	118	700	92	60				
12:00	58.5	63.2	4.84					140	560			140	560	130	520	760	2300	3760	105	150	105	150			118	390	91	118	700	91	60				
1:00	58.5	63.2	4.84					140	560			140	560	130	520	760	2300	3760	105	150	105	150			118	390	91	118	700	91	60				
2:00	58.5	63.2	4.84					140	560			140	560	130	520	760	2300	3760	105	150	105	150			118	390	91	118	700	91	60				
3:00	58.5	63.2	4.84					140	560			140	560	130	520	760	2300	3760	105	150	105	150			118	390	91	118	700	91	60				
4:00	58.5	63.2	4.84					140	560			140	560	130	520	760	2300	3760	105	150	105	150			118	390	91	118	700	91	60				
5:00	58.5	63.2	4.84					140	560			140	560	130	520	760	2300	3760	105	150	105	150			118	390	91	118	700	91	60				
6:00	58.4	63.1	4.73					140	560			135	540	130	520	760	2300	3720	105	150	105	150			118	390	91	118	700	91	60				
7:00	58.4	63.1	4.73					140	560			135	540	130	520	760	2300	3720	105	150	105	150			118	390	91	118	700	91	60				
8:00	58.4	63.1	4.73					140	560			135	540	130	520	760	2300	3720	105	150	105	150			118	390	91	118	700	91	60				
9:00	58.4	63.1	4.73					140	560			135	540	130	520	760	2300	3720	105	150	105	150			118	390	91	118	700	91	60				
10:00	58.4	63.1	4.73					140	560			135	540	130	520	760	2300	3720	105	150	105	150			118	390	91	118	700	91	60				
11:00	58.4	63.1	4.73					140	560			135	540	130	520	760	2300	3720	105	150	105	150			118	390	91	118	700	91	60				
12:00	58.4	63.1	4.73					140	560			135	540	130	520	760	2300	3720	105	150	105	150			118	390	91	118	700	91	60				
1:00	58.5	63.2	4.84					140	560			135	540	130	520	760	2300	3760	105	150	105	150			118	390	91	118	700	91	60				
2:00	58.5	63.2	4.84					140	560			135	540	130	520	760	2300	3760	105	150	105	150			118	390	91	118	700	91	60				
3:00	58.5	63.2	4.84					140	560			135	540	130	520	760	2300	3760	105	150	105	150			118	390	91	118	700	91	60				
4:00	58.5	63.2	4.84					140	560			135	540	130	520	760	2300	3760	105	150	105	150			118	390	91	118	700	91	60				
5:00	58.4	63.1	4.73					140	560			135	540	130	520	760	2300	3720	105	150	105	150			118	390	91	118	700	91	60				
6:00	58.4	63.1	4.73					140	560			135	540	130	520	760	2300	3720	105	150	105	150			118	390	91	118	700	91	60				
7:00	58.4	63.1	4.73					140	560			135	540	130	520	760	2300	3720	105	150	105	150			118	390	91	118	700	91	60				
8:00	58.6	63.0	4.42							155	560	115	440			720	2200	3125	115	135	115	135			120	360	91	120	560	92	60	103	15	1211	78
9:00	58.6	63.3	4.73							150	560	135	540			720	2200	3565	125	150	125	150			122	370	90	122	600	90	60				
10:00	58.6	63.1	4.52			60	200			145	520	135	540			680	2200	3410	115	160	115	160			122	370	91	122	600	91	60				
11:00	58.5	63.1	4.62			60	120			150	580	135	540			720	2200	3900	115	165	115	165			122	370	90	122	550	90	60				
12:00	58.5	63.1	4.62							145	520	135	540			680	2100	3100	115	135	115	135			122	370	90	122	540	90	60				
1:00	58.4	63.1	4.73							75	200	140	560			700	2200	2900	115	135	115	135			121	360	91	121	520	91	60				
2:00	58.4	63.0	4.57							75	200	125	500			640	2000	2675	110	125	110	125			120	340	90	120	500	90	60				
3:00	58.4	62.9	4.52									100	400			600	1900	2325	105	135	105	135			118	180	93	118	420	93	60				
4:00	58.5	63.1	4.58													660	2050	2000	100	135	100	135						118	520	94	60	100	1.5	1207	77
5:00	58.6	63.9	5.30													600	1850	1775			95	100						114	410	90	60				
6:00	58.6	63.9	5.30													640	2000	2050			100	100						114	520	94	60				
7:00	58.6	63.9	5.30													620	1900	1800			100	100						114	480	94	60				
8:00	58.7	63.9	5.21													640	1950	1800			100	100						114	520	94	60	135	1.0	1206	78
9:00	58.7	63.9	5.21													560	1700	1600			100	100						114	450	94	60				
10:00	58.7	63.9	5.21													600	1850	1760			100	100						114	450	94	60				
11:00	58.8	63.9	5.12													580	1750	1600			100	100						114	500	94	60				
12:00	58.8	63.9	5.12													640	1950	2000			100	100						114	520	94	60	139	1.0	1210	80
1:00	58.8	63.9	5.12													640	2000	1925			100	100						114	540	94	60				
2:00	58.9	63.9	5.03													620	1900	2000			95	100						114	500	94	60				
3:00	58.8	63.9	5.12													580	1800	1725			95	100						114	490	93	60				
4:00	58.8	63.9	5.12													580	1750	1700			105	110						114	460	93	60	113	1.5	1213	79
5:00	58.7	63.9	5.21													620	1850	2200			110	120						118	560	92	60				
6:00	59.0	63.9	4.92							90	300					560	1800	2580			100	200						118	610	95	60				
7:00	59.0	63.9	4.92							100	400	100	360			560	1800	2580			100	200						118	610	95	60				

TIME OF READINGS	STEAM PRESSURE	1ST STAGE PRES. ON TURBO NO. 1	1ST STAGE PRES. ON TURBO NO. 2	1ST STAGE PRES ON TURBO NO. 3	CONDENSERS VACUUM 1	VACUUM 2	VACUUM 3	NO. 1 INTAKE	NO. 1 DISCHARGE	NO. 1 HOT WELL	NO. 2 INTAKE	NO. 2 DISCHARGE	NO. 2 HOT WELL	NO. 3 INTAKE	NO. 3 DISCHARGE	NO. 3 HOT WELL	TRANSFORMERS TEMPERATURES F° A 6	A 5	A 4	A X-A	A X-B	B 3	B 2	B 1	BAROMETER	TEMPERATURES INSIDE	OUTSIDE	FILTER	FEED WATER	STEAM SUPERHEAT	FEED PUMPS	BOILER PRESSURE	FEED WATER LBS.
1:00		0	0	52				71	89	103	78	95	103	78	96	96	30	30	30			46	42	40	29.4	93							
2:00		0	0	46				71	89	104	78	96	105	78	95	96	32	32	32			47	43	40	29.6	93	78	118					
3:00		0	0	43				78	89	105	78	96	104	78	90	96	34	34	34			47	43	40	29.8	94		120					
4:00		0	0	50				71	89	105	78	96	103	78	90	94	35	35	35			47	43	41	29.9	94		122					
5:00		0	0	54	"	"	"	78	93	104	78	97	103	78	89	96	36	36	36			47	43	41	29.9	95		124					
6:00		0	0	45	"	"	"	78	93	106	78	95	103	78	90	96	36	36	36			48	44	41	29.9	95	76	126					
7:00		0	0	56	"	"	"	78	92	104	78	93	103	78	94	94	38	38	38			48	44	41	29.9	96		128					
8:00		6	4	58	"	"	"	78	92	106	78	91	104	78	90	94	40	40	40			49	45	42	29.9	97		130					
9:00		0	0	61				78	92	106	78	93	104	78	92	96	41	41	41			49	45	42	29.9	98		132					
10:00		6	5	53				78	91	106	78	89	103	78	92	96	42	42	42			49	45	42	29.9	98	80	132					
11:00		10	4	54				78	89	106	78	89	104	78	92	96	42	42	42			50	45	42	29.9	98		132					
12:00		4	0	45				78	90	103	78	92	110	78	92	96	42	42	42			49	45	42	29.9	98		134					
1:00		0	0	58				78	92	103	78	91	103	78	90	94	42	42	42			49	45	42	29.9	99		134					
2:00		0	0	56				78	90	104	78	90	103	78	90	96	43	43	43			49	44	42	29.9	100	86	136					
3:00		0	0	59				78	91	105	78	90	103	78	91	96	44	44	44			49	44	42	29.9	99		136					
4:00		0	0	53				78	92	103	78	89	103	78	94	96	44	44	44			49	44	42	29.9	98		136	139				
5:00		10	10	50				78	91	103	78	88	103	78	96	96	43	43	43			49	44	41	29.9	96		136					
6:00		4	4	46				78	90	103	78	88	103	78	90	94	43	43	43			49	44	41	29.9	96	78	136					
7:00		8	4	40				78	88	103	78	87	103	78	88	92	43	43	43			49	44	41	29.9	97		136					
8:00		6	10	38				78	88	103	78	87	103	78	88	90	43	43	43			49	44	41	29.9	97		138					
9:00		10	12	42				78	88	103	78	87	102	78	90	92	43	43	43			49	43	40	29.9	97		138					
10:00		10		40				78	87	104				78	91	94	43	43	43			49	43	40	29.9	96	80	138					
11:00		10		30				78	88	104				78	90	94	42	42	42			48	43	40	29.9	96		138					
12:00		10		34				78	88	104				78	90	92	42	42	42			47	43	39	29.9	96		138	132				
1:00		10		50				78	88	104				78	92	94	42	42	42			47	43	39	29.9	95		138					
2:00		8		50				78	88	104				78	91	94	42	42	42			46	41	38	29.9	95	76	138					
3:00		0		52				78	92	106				78	92	95	42	42	42			47	43	39	29.9	95		134					
4:00		0		54				78	94	108				78	90	94	42	42	42			47	43	39	29.9	95		130					
5:00		0		54				78	93	108				78	90	94	44	44	44			47	43	39	29.9	95		132					
6:00		2		54				78	93	108				78	90	94	44	44	44			47	43	39	29.9	95		134					
7:00		0		48				78	93	108				78	90	94	44	44	44			48	43	40	29.8	96	77	134					
8:00		0		44				78	94	108				78	90	94	44	44	44			47	43	39	29.8	95		134					
9:00		0		44				78	92	108				78	90	94	44	44	44			47	43	39	29.8	95		134	137				
10:00		0		44				78	93	108				78	90	94	44	44	44			47	43	40	29.8	94		134					
11:00		0		44				78	93	108				78	90	94						47	43	40	29.8	93	76	134					
12:00				46				X	X	X				78	90	94						47	43	40	29.8	93	76	134					
1:00				44				X	X	X				78	90	94						47	43	40	29.8	93		134					
2:00				44				X	X	X				78	90	94						47	43	40	29.8	93		134					
3:00				46				X	X	X				78	90	94						47	43	40	29.8	93		134					
4:00				42				X	X	X				78	89	93						47	43	40	29.8	93	76	134					
5:00				40				X	X	X				78	89	93						46	43	39	29.8	93		134					
6:00				40				X	X	X				78	89	93						46	43	39	29.8	93		134					
7:00				40				X	X	X				78	89	93						46	43	39	29.8	93		134					
8:00				40				X	X	X				78	89	93						46	43	39	29.8	93		134					
9:00				40				X	X	X				78	89	93						46	43	39	29.8	93		134					
10:00				40				X	X	X				78	89	93						46	43	39	29.8	93		134					
11:00				40				X	X	X				78	89	93						46	43	39	29.8	93		134					
12:00				42				X	X	X				78	89	93						46	43	39	29.8	93		134					
1:00				40				X	X	X				78	88	92						45	41	38	29.8	93		134					
2:00				30				X	X	X				78	88	90						45	41	38	29.8	93		134					
3:00				36				X	X	X				78	88	92						45	41	38	29.8	93		134					
4:00				40				X	X	X				77	87	90						44	39	37	29.8	93		134					
5:00				40				77	85	99				77	87	90						44	38	37	29.8	94		134					
6:00																																
7:00																																

Show Time of Each Cleaning of Fires by Star *

TIME OF READINGS	DRAUGHT AND TEMPERATURE 1 PYROMETER	1 DAMPER	2 PYROMETER	2 DAMPER	3 PYROMETER	3 DAMPER	4 PYROMETER	4 DAMPER	CO₂
1:00									
2:00									
3:00									
4:00									
5:00									
6:00									
7:00									
8:00									
9:00									
10:00									
11:00									
12:00									
1:00									
2:00									
3:00									
4:00									
5:00									
6:00									
7:00									
8:00									
9:00									
10:00									
11:00									
12:00									
1:00									
2:00									
3:00									
4:00									
5:00									
6:00									
7:00									

REMARKS

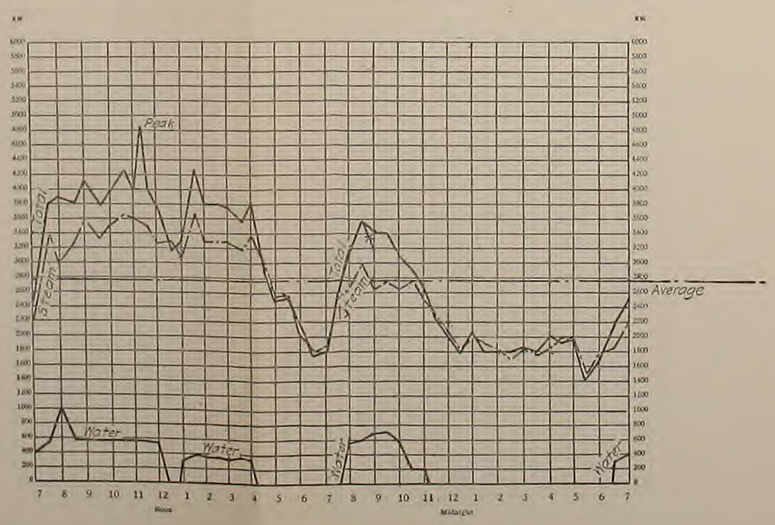
NOTE. STATE ONLY SUCH FACTS WHICH INTERFERE WITH OPERATION OR CONDITION OF RUNNING.

Hourly Rates of Pond = .0769 ft.

7:20 Unit #1 on Boiler =
8:06 " A + B Bank " =
8:30 " #2 Steam Turbo on
9:00 " #5 Gen. on Load
8:30 Ducts Cleaning Fires.
10:00 #2 " Gen Off
10:30 #05 " #4 " on Load
11:00 #25 " #4 " off "
11:30 #20 " #5 " " "
12:00 #35 " #5 " on Load
11:30 #00 " 721 227 232 241 Pm.
1:00 " 1100 Volts out for 5 min
1:30 Lightning Current by Lightning
2:00 #45 Pm Killed & Reinsulated
2:30 #100 V Lines as requested by
3:00 Mr. Torrence to Town & Ph. Lines
3:30 Pm Lines replaced all Mater
4:00 Field wires having been
4:30 Cleared by Lightning
5:00 #50 " #100 Volts also O.K
5:30 Water Heat as requested
6:00 Mr. Brown. "
6:30 #45 " #5 Gen off Load
7:00 5:10 Pm #2 turbo " "
7:30 #45 " #5 Gen on Turbo
8:00 #55 " #5 " off "
8:30 #04, 18 #21 Coal Pocket Filled up
8:00 Harmston Excavator Loaded
9:30 7:37 Pm #2 Gen on Load
10:00 #31 " #4 " " "
10:30 #50 " #4 " off "
11:00 #04 Picked up Scott Excavator
11:30 Load from #21 Coal Plant
12:00 #12 Pm #6 Gen off Load
12:30 " #1 A Bank " "
1:00 #41 " #1 Turbo " "
1:30 #00 Switchboard Co. #14-
2:00 #1 Turbo off Load
2:30 #32 Pm Indian Valley Load
3:00 Battery Charging
3:30 #02 Pm Legal Valley off Col
4:00 Battery Charged
4:30 #00 Pm Rawhide Load #18
5:00 #09 " #6 Gen on Load
5:30 #35 " #1 Turbo " "

INTEGRATING WATT METERS

7:00 A. M.	BANK A	BANK B	No. 1 TURBO	No. 2 TURBO	No. 3 TURBO	No. 3 STEAM EXCITER	TOTAL STATION OUTPUT	TOTAL STEAM OUTPUT	TOTAL WATER OUTPUT BY DIFFERENCE
PRESENT	9600	10496	234090	200410	518190	151930			
PREVIOUS	9583800	9574300	192920	513940	105180	2489			
DIFFERENCE	17100	49200	7490	4250	46750		66300	58490	7810



COAL LBS.	WATER LBS.		KW HRS.	APAR. EVAPOR.		STEAM PER KW HR.		LBS COAL PER KWH.	LOAD FACTOR
									75.8%
1st Shift 64145	506700	1st Shift	33500	7.93	1st Shift	21.50	1st Shift	2.63	68.5%
2d Shift 48700	411000	2d Shift	24990	8.47	2d Shift				69.7%
3d Shift 34200	304500	3d Shift	24990	8.93	3d Shift	20.08	2d Shift	2.35	62.7%
TOTAL 147045	1222200	TOTAL	58490	8.36	AVE.	20.85	AVE.	2.51	57.1%

LIGHTNING ARRESTERS

A TIME	A CONDITION	B TIME	B CONDITION	C TIME	C CONDITION	
4:20 Am	Blue	4:20 Am	Blue	4:20 Am	Blue	CHARGING
						DISCHARGE
						DISCHARGE

NOTE. Show on diagram half hourly the output in KW of steam driven generators, water wheel driven generators, and total KW generated separately.

I have recorded the above data and report them as correct
9 H B Ferguson DAY RIGHT 8 1 13
M K Tillson DAY RIGHT 8 1 13
Checked S D Pratt Syst. DAY RIGHT MONTH DAY YEAR

COAL STATEMENT	DATE RECD.	DATE RELEASED	LBS.
Car No. 36147+BT. R.R.	7/30	8/1/13	104800
" 3193 " " "	8/1	8/1/13	108000
" " "			
" " "			
" " "			
TOTAL NEW DELIVERY			212800
PREVIOUS BALANCE			692525
ON HAND AT 7:00 A. M.			905325
USED RUNNING			147045
USED BANKING			3750
TOTAL CONSUMED			150795
BALANCE ON HAND			754530

FIG. 92.—ACTUAL DAILY LOG REPRODUCTION

Log picked at random representing daily entries and a summary by shift of a plant of a public utility company operated under the author's regime. Task work with secondary rate wages recently inaugurated. Plant is a combination of carbo-electric and hydro-electric installations of 6000 kw. capacity.

If readings are not taken or instrument was out of order, no entry shall be made but a question mark (?) written in place indicating uncertainty.

Engine Room Log P 2 is kept by watch engineer, it is dated at 6 A. M. when started and returned to office after 24 hours for computation. It registers:

Hourly
1 Readings of electrical instruments
2 Units and auxiliaries in use

At the end of each shift
3 Meter readings (steam and water)
4 Revolution counters
5 Oil used
6 Men working
7 Condenser temperature (at 8, 12 and 4 o'clock)

Watch engineers do not figure out differences, constants, averages or summary, this being done by power house clerk.

If readings are not taken or instrument was out of order, write in a question mark (?) instead of guess figure.

Keep notes on special occurrences under "Remarks" such as interruptions, unusual conditions, accidents, absence from plant, etc.

Figuring Out Log. The Power House clerk receives both sections of daily power house log and before proceeding with figuring out totals and results secure following information.

1 Chart showing temperature of water entering economizer

2 Steam pressure chart

and finds from the curves average temperature and pressure for each of 3 shifts, 6-2, 2-10, 10-6. He then verifies that the time cards stamps correspond with log entries under "crew" and that oil used is covered with stores issues. He then proceeds to figure out the data and results in accordance with the instructions on the subject.

Filing Log. When log is figured out and daily power plant report is made out, the clerk places it on the Chief Operating Engineer's desk who checks it and signs it. The daily power plant report is then sent to the General Superintendent and the log filed in clamps provided for each month of a year and placed on the log rack. At the end of a year last month logs are removed from the clamps and placed in transfer file.

Service Records

Service records are sometimes available from the power-house log but being substantially the records of service rendered to consumer cannot be complete unless the data of distribution, interruption, line and transmission losses, etc., are available besides the data of plant output and the form in which the power was sent out.

In the case of a central electric station, the service record thus include all occurrences, phenomena, and data beyond the station busbars, comprising lines, transformers, sub-stations, etc., up to the customer's entry. In case of a manufacturing plant the service records should picture all that happens to power beyond the power plant walls and up to the point where the power actually serves its purpose, though the efficiency of utilization of that power is not a matter of plant service.

Distribution of Power. Records showing how the power was distributed among various places of consumption are important not only from the operating view point, indicating what lines and at what time are crowded, what is the general tendency of load and so forth, but also and particularly serviceable for the general management and service department. In case of a central electric station it is frequently advisable to represent such records in form of curves on time scale as abscissa and several coördinates like kilowatt hours, voltage, frequency, temperature of transformers, etc. In cases of manufacturing plants records of distribution are of great value for ultimate analysis of the cost of power service to various departments and relative economy of use of different forms of power in which it may be sent out from the power plant. While this function may not be considered properly within the domain of the plant operation, such close coöperation between producing and consuming departments does invariably produce beneficial results for both as lessening of waste in consumption and distribution reflects on power-plant economy.

The form represented in Figure 94 illustrates the manner in which a manufacturing concern using power in large quantity in a variety of forms finds it convenient and beneficial to record the distribution of power. The use of these records has led to many improvements and economies making the work involved highly productive.

Interruption of Service. Records of interruption in service commend themselves as indispensable either in public service company or in a private industrial plant. The activity, comfort, and even

ING AT 6 A. M.

YEAR

TIME

REMARKS:

FORM P. 1

POWER PLANT LOG

FOR 24 HRS. BEGINNING AT 6 A. M.

MONTH	DAY	YEAR

BOILER ROOM

TIME	IN SERVICE: BOILERS 1 2 3 4 5 6 7 8	ECONOM. 1 2 3	COAL CRUSH. ENGINE	HEATERS 1 2 3	STEAM PRESS.	FLUE GAS: TEMPERATURES 1 2 3 4 5 6 7 8 SC SW	STEAM FLOW METERS: BOILER NUMBERS 1 2 3 4 5 6 7 8
6							
7							
8							
9							
10							
11							
12							
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
1							
2							
3							
4							
5							

BOILER ROOM CREW

NAME	NO.	WORK	REMARKS	HRS.	SHIFT

COAL STATEMENT

R. R. CO.	CAR NO.	TIME: RECD.	TIME: UNLOAD	TIME: DRILL OUT	ANTHRACITE	BITUMINOUS

TOTAL NEW DELIVERY	
UNLOADED IN 24 HOURS	
PREVIOUS BALANCE	
TOTAL AVAILABLE	
SOLD	
TAKEN TO REFINERY	
BRUSH & COMB	
USED IN POWER PLANT	
TOTAL ISSUED	
BALANCE ON HAND AT 6 A. M.	

LEGEND:

- ▭ (BLACK) MADE BONUS _____ SIGNED: _____
- ▭ (RED) LOST " _____ 1st SHIFT
- ▭ (BLACK) DAY WORK _____ 2nd "
- ▭ (RED) ABSENT _____ 3rd "
- —— TIME RUNNING _____ CH. ENG
- ∧∧∧ RUN WITHOUT LOAD _____

DRAFT ON BOILERS

TIME	DRAFT	BOILERS 1	2	3	4	5	6	7	8
6	DAMPER								
	FURNACE								
7	DAMPER								
	FURNACE								
8	DAMPER								
	FURNACE								
9	DAMPER								
	FURNACE								
10	DAMPER								
	FURNACE								
11	DAMPER								
	FURNACE								
12	DAMPER								
	FURNACE								
1	DAMPER								
	FURNACE								
2	DAMPER								
	FURNACE								
3	DAMPER								
	FURNACE								
4	DAMPER								
	FURNACE								
5	DAMPER								
	FURNACE								
6	DAMPER								
	FURNACE								

REMARKS:

COAL REPORT FOR

SHIFT NO. _____ DATE _____

2 & 4 SOFT	2 & 4 HARD	1, 3, 5 & 7 SOFT	1, 3, 5 & 7 HARD

TOTAL SIFTINGS
TOTAL BANKING BLRS. NO. _____
TOTAL SOFT
TOTAL HARD
TOTAL COAL FOR SHIFT

SHIFT NO. _____ DATE _____

2 & 4 SOFT	2 & 4 HARD	1, 3, 5 & 7 SOFT	1, 3, 5 & 7 HARD

TOTAL SIFTINGS
TOTAL BANKING BLRS. NO. _____
TOTAL SOFT
TOTAL HARD
TOTAL COAL FOR SHIFT

SHIFT NO. _____ DATE _____

2 & 4 SOFT	2 & 4 HARD	1, 3, 5 & 7 SOFT	1, 3, 5 & 7 HARD

TOTAL SIFTINGS
TOTAL BANKING BLRS. NO. _____
TOTAL SOFT
TOTAL HARD
TOTAL COAL FOR SHIFT

P. 2

POWER PLANT LOG

FOR 24 HRS. BEGINNING AT 6 A. M.

MONTH	DAY	YEAR

ENGINE ROOM

TIME	TURBO GENERATORS: AMPERES 1 2 3 4	VOLTS	TEMP. BEARINGS 1 2 3 4	O. C. GENERATORS: VG 40 AMP.	VG 50 AMP.	VOLT	TRANSFORMER: 40 K.W. BN'K 1 2 3	26 K.W. BN'K 1 2 3	IN SERVICE: AIR COM. 1 2 3	ICE MACH. 1 2 3 4	PUMPS: HYD'IC VH 10	VH 20	VH 30	FEED VB 15	VB 10	VB 110	C. AIR	HUM.	VG 19	VG 113	WATER VW 11	VW 21	VW 22	VW 2	VW 23	COOLING TOWER DROUGHT N	F
6																											
7																											
8																											
9																											
10																											
11																											
12																											
1																											
2																											
3																											
4																											
5																											
6																											
7																											
8																											
9																											
10																											
11																											
12																											
1																											
2																											
3																											
4																											
5																											
6																											

STEAM FLOW METER, MFG.

SHIFT	LAST READ.	PREV. READ.	DIFF.
1			
2			
3			

WATER METER NO. 1, HOUSE

SHIFT	LAST READ.	PREV. READ.	DIFF.
1			
2			
3			

WATER METER NO. 2, DAMPER

SHIFT			
1			
2			
3			

WATER METER NO. 3, HYDRAULIC

SHIFT			
1			
2			
3			

WATER METER NO. 4, RETURN

SHIFT			
1			
2			
3			

WATER METER NO. 5, HEATER

SHIFT			
1			
2			
3			

WATT METER NO. 1

SHIFT			
1			
2			
3			

WATT METER NO. 2

SHIFT			
1			
2			
3			

WATT METER NO. 3, M.G. SET

SHIFT			
1			
2			
3			

REVOLUTION COUNTERS

TIME	ICE MACHINES VR-10	VR-20	VR-30	VR-40	PUMPS VH-10	VH-20	VH-30	VW-2	VW-23	VF-1
2-P.M.										
6-A.M.										
DIFF.										
10-P.M.										
2-P.M.										
DIFF.										
6-A.M.										
10-P.M.										
DIFF.										

REPUBLIC STEAM FLOW METERS

SHIFT	METER	START	END	DIFF.	LBS. WATER
1	1				
	2				
	3				
	4				
	5				
	7				
	TOTAL				
2	1				
	2				
	3				
	4				
	5				
	7				
	TOTAL				
3	1				
	2				
	3				
	4				
	5				
	7				
	TOTAL				

STEAM FLOW METER, TOTAL

SHIFT	METER NO.	END	START	DIFF.	TOTAL
1	1				
	2				
2	1				
	2				
3	1				
	2				

TOTAL WATER FOR TODAY =

OIL USED GALS.

SYMBOL	CYLINDER 1 2 3	TURBINE 1 2 3	ENGINE 1 2 3
SHIFTS			
TOTALS			

SUMMARY DATE _____

	SHIFTS 1	2	3
COAL CONSUMED, TOTAL			
COAL CONSUMED, BANKING			
COAL CONSUMED, POWER HOUSE			
WATER EVAPORATED			
BOILER PRESSURE			
TEMPERATURE OF WATER TO ECONOMIZER			
FACTOR OF EVAPORATION			
EQUIV. EVAP. PER LB. OF COAL			
B.T.U. PER POUND OF COAL			
EFFICIENCY OF BOILERS			
COST OF COAL PER M. LBS. OF STEAM			
K.W.H. GENERATED			
CU. FT. FREE AIR COMPRESSED			
FOOT-POUNDS HYDRAULIC WORK			
ICE MACHINE			
STEAM FOR MANUFACTURING			
% OF IDLE PLANT CAPACITY			

REMARKS:

TURBO CONDENSER RECORD

TIME	VG-12		VG-22		VG-32		TEMP. INTAKE	
6-A.M.								
12-A.M.								
4-P.M.								
6-P.M.								
12-P.M.								
4-A.M.								

ENGINE ROOM CREW

NAME	NO.	JOB	BONUS 1	2	3	HRS.

SIGNED:

_____ 1st SHIFT
_____ 2nd "
_____ 3rd "
_____ CH. ENG.

FIG. 93.—LOG OF A MEDIUM SIZE MILL POWER HOUSE

This log is split into two sections: for boiler house and engine room; each section is kept separately because of arrangement of the plant; both halves are pasted together in the plant office next morning when checked and calculated.

POWER PLANT

BOILER ROOM

| TIME | BOILERS | | | | | | | | ECONOMIZERS | | | | | | | | HEATERS | | | | | | | |

POWER COSTS DISTRIBUTION

Date.....

Main Power Plant	Electricity		Pneumatic (Well Water)		Refrigeration		Steam & Heat		Hydraulic		Total Power Changes	
Departments	$	%	$	%	$	%	$	%	$	%	$	%
1. Acid		32.30		41.30				21.05		1.52		
2. Converting		29.90		8.83				5.20		28.18		
3. Sheeting		2.58		16.88				8.18		20.83		
4. Stuffing		.45		1.30				5.62		11.04		
5. Finishing		.44		24.70				14.47		14.38		
6. Stock Room		.06						.89				
7. Seasoning		.78						14.66				
8. Testing		.03						.11				
9. Mfg. Laboratory		.02						9.63				
10. Mfg. General		.94						.27				
11. Laboratory		.07										
12. Collar & Cuff		2.49		1.47				.60		1.01		
13. Collar & Cuff Shipping		.01						.16				
14. Novelty		1.25		2.40				9.05		10.29		
15. Specialty		4.30		3.12				6.19		12.15		
16. Roll Celluloid		12.00				100.00		7.90				
16. Lower End		10.90										
18. Executive		.28						.89				
19. Repair Shops		1.20						.89				
20. Totals		100.00		100.00		100.00		100.00		100.00		
21.		44.52		10.29		11.15		20 91		3.13		

Lower End Distribution	Electricity Sub-Division				Isolated Plant Charges			
	Electricity		Well Water		Steam & Heat		Hydraulic	Total
22. Brush		31.60		3.71		22.48	7.53	
23. Comb		28.70		3.71		22.48	7.53	
24. Scrap		12.45			No. 2 B. H.	8.82		
25. Texoderm		1.38				14.71		
26. Camphor Refinery		6.92				16.45		
27. No. 3 B. H. (895)		2.93						
28. No. 4. B. H. (Refinery)		8.60						
29. Total		92.58		7.42		84.94	15.06	

FIG. 94.—POWER COSTS DISTRIBUTION REPORT

safety of customer depends on uninterrupted supply of power. Manufacturing plants or transportation lines cut off from power supply even for a short time suffer sometime very serious loss or damage and therefore any cause, duration, location and nature of interruption must be carefully recorded, and analyzed and clearly presented, serving both as an explanation and as a lesson for future avoidance and safeguarding against.

The data for the records of this nature are collected usually by the load despatcher or, in smaller plants by operating engineer. The presentation of these facts gains in clearness and usefulness if, instead of merely being written down on a log are also presented in a graphic form. A convenient and successful method of recording line interruptions is illustrated in Figure 95. It is a straight line record extending over the period of 24 hours analyzing troubles and interruptions first as to cause, such as: lightning, grounded line, substation failure, power-house failure, accident to man, repairs, insulator trouble, and any other cause. Next the trouble is allocated to a line, section substation, branch, customer or in any other desirable manner. For the period of any interruption a red line of its duration is drawn to time scale both opposite the cause and on the line involved; if disturbance was of a momentary character so that a line would be too short, it is checked at the time with a letter symbolizing the nature of disturbance written on top such as R—denoting resistance in—resistance out, etc. Systematic study of such records was found extremely serviceable in developing needed improvements for material reduction of main or more frequent causes of interruption.

Character of Service. Finally the records classifying and analyzing the service as to its character shall not be omitted, as information secured along these lines inevitably lead to both improved service and increased economy. It has been thus recognized in many instances that a change from direct current service to alternating current offers so many advantages that the investments necessary for such change are desirable both for the community served and the concern rendering service. There is still a large field of meagerly investigated questions of similar nature and financial reports alone, which without full elucidation and support by fundamental facts disclosed by service records, are frequently misleading and either retard the progress of the community or drag the public service company into financial embarrassment.

Similarly, in an industrial power plant, generating electric, pneumatic, hydraulic and direct mechanical power, besides furnishing refrigeration, live and exhaust steam for manufacturing processes,

etc., it is sometimes a vital problem to find out the corresponding efficiency of each kind of power, and thus furnish the basis for determining relative economies in their use. In many instances the departments using certain kinds of power (compressed air for instance) are not at all certain that it is cheaper than motor drive.

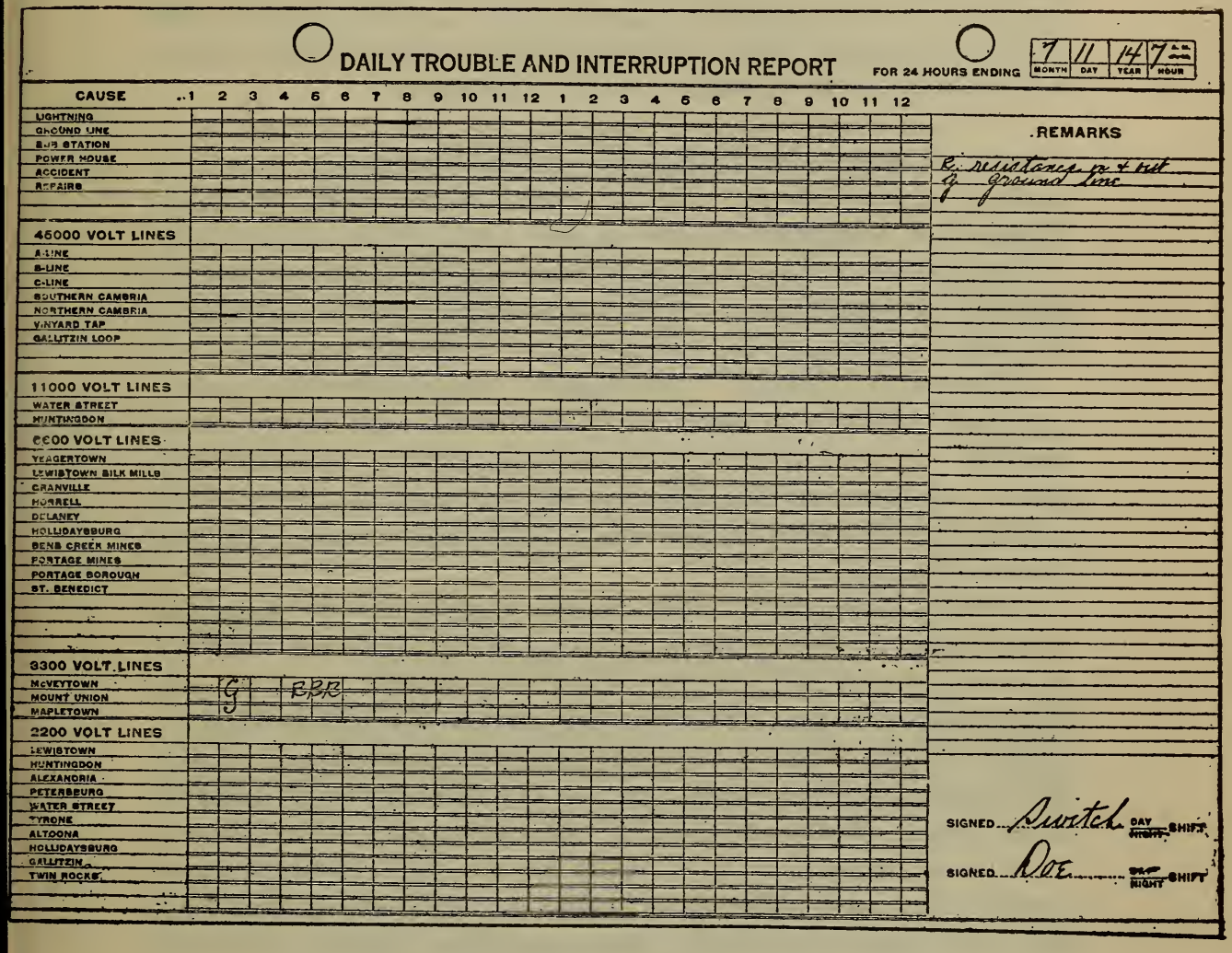


FIG. 95.—DAILY TROUBLE AND INTERRUPTION REPORT

It visualizes affected feeders and lines as well as indicates graphically duration of interruption and time of occurrence; cause of it is indicated both in classified top section and by symbol letter. Space for remarks is provided for more detailed report by load despatcher.

Similar questions are becoming particularly important in shops where substitution of one kind of power by another does not require change of equipment but merely methods. Again no change of equipment should be decided upon unless the cost of service is firmly established. Almost all the tests and calculations are misleading, so long as they do not account for leaks and other losses in distribution and use

which might entirely upset the cost of generation alone. Accurate records of such a nature are capable of throwing the correct light on the problem. Figure 96 shows that in a large machine shop, after the efficiency and cost of different forms of power were studied from a set of comprehensive records, efforts were made to use a least expensive form whenever and wherever possible. The result was very material reduction of power-plant expenses, although some of the departments had a somewhat larger power bill than when it was lowered at the expense of other departments.

In a plant manufacturing electricity for sale a complete set of records differentiating between direct and alternating current as well as between 25 and 60-cycle output of the latter are almost always kept, though not always properly used. As a result in determining the bus-bar cost these differences are frequently disregarded and the customer's rates are not necessarily adjusted according to the cost of manufacturing various forms of electric power.

Construction Records. The effect of rapid construction or alteration and additions to plants on its first cost is not always clearly realized. It is reported that in academic cloisters sometimes time passes unheeded, but the plans laid out for productive work or for construction of means of production without due regard as to time consumed are of no use.

Perhaps managers of capital would recognize clearly enough the disadvantage of slowing down the completion of the work from two to three years in order to gain 42 per cent instead of 34 per cent upon the fixed capital. But when the question lies between different lengths of time under a year, for instance between three, four or five months, it is frequently the case that the advantages of quick work remain wholly unrecognized and neglected.[114]

It is of importance to carefully lay out the schedule of work contemplated, and definitely determine the task as to time when materials shall be delivered, which operations precede and which follow and when each shall be completed. This obviously is not all. "The road to hell is paved with good intentions," and we should have a clear, continuous record of progress if we want to know whether we are living up to our task and if not, where and how much, we are behind the schedule.

Waste of time in any activity giving advantages to those who do not wait and this means more than financial competition. The whole trend of our progress, the entire development of our technique is characterized in two words, "time saving." From high-speed steel to the fastest aeroplane, from short-hand notes to wireless

telephone, everything is calculated to accomplish the most in minimum time. Since sanitation, hygiene, and medical arts, are as yet hardly able to appreciably prolong our life, it became a task of an engineer to make possible for one to accomplish most within his limited life-time.

Upon the insistence of the author, at that time Power Expert for the United States Shipping Board, Emergency Fleet Corporation, several public utilities began to use construction records in

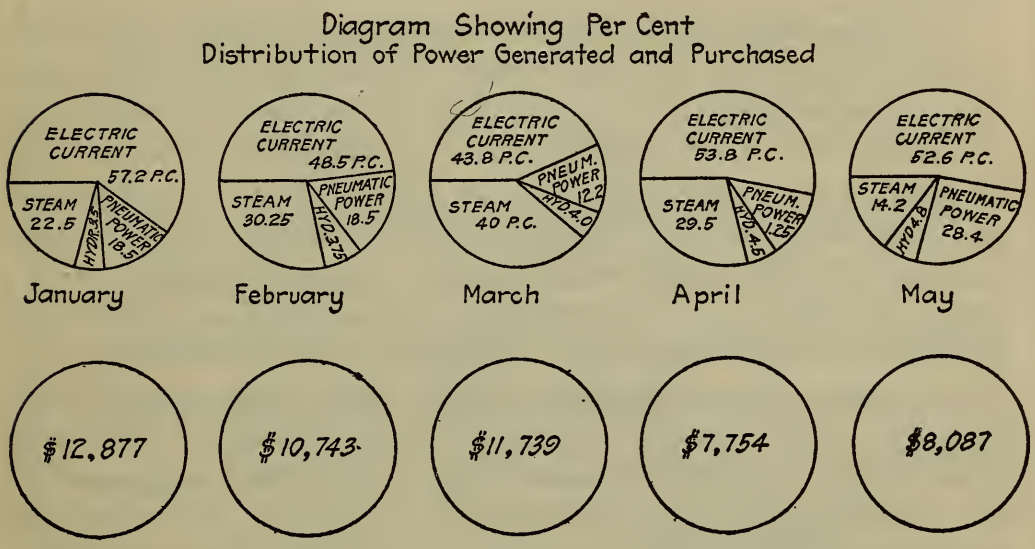


FIG. 96.—POWER DISTRIBUTION RECORD

A large manufacturing concern using power in four different forms used this diagram to study relative expenses of various forms of power. It led to a material reduction of fuel consumption by substitution of some forms of power by another for use in the shops. Circular form of percentage distribution is lacking clearness which straight line charts have.

a graphic form, plotting charts in straight line representing the part of work done against the time scale allowed for the work. By days, weeks, and months the length of the bar show how much of schedule work was accomplished each day or month, a heavy summary line indicating the progress of work to date of the record entry. Any delay was explained by a symbol denoting the cause of same thus helping the supervising official to render his service and direct efforts in eliminating the cause. Figure 40 illustrates a similar record of progress in construction of boilers. Obviously the same method is equally adaptable to erection or any other work.

Analyzing Data

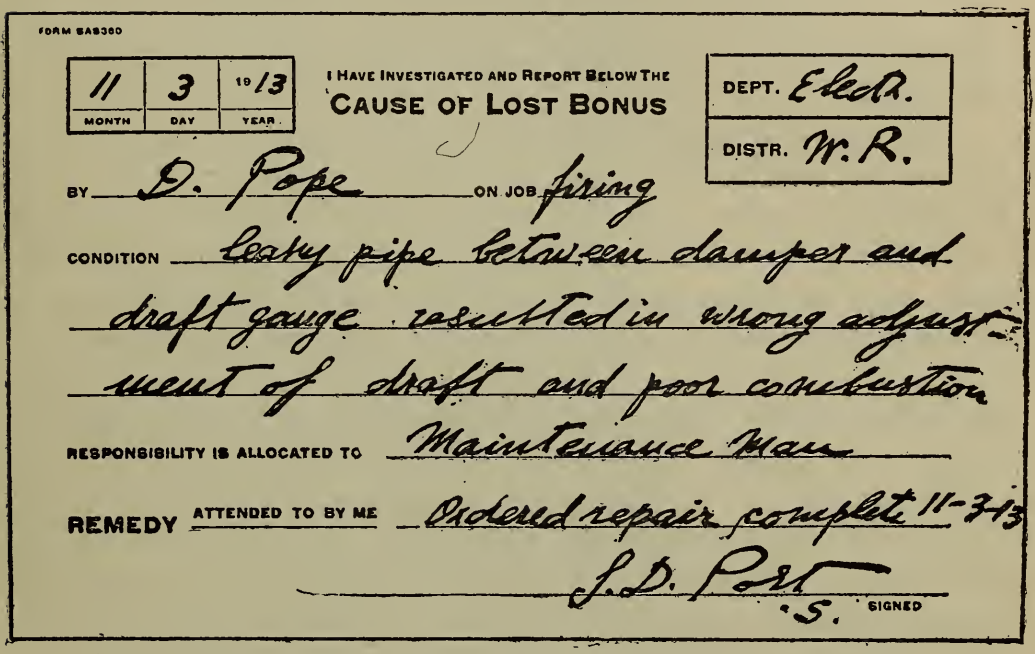
As anything so detailed and complete as the elaborate large log is liable to be filed away before the man in charge of the plant operation gets the benefit of its study, a concentrated summary should be made either on the log or on a separate slip, for the quick information of those primarily interested in the results, while any further information could be secured from the complete log, instrument charts, etc., whenever a detailed study of operating conditions is needed.

As it has been said in regard to men's performance, the record of their living up to their task must be analyzed before the same crew comes back to work in order to secure the benefit of experience and prevent the recurrence of mistake (see Figure 97), so it is with the general performance records. In fact in only a few cases can the judgment as to man's performance be formed without a close study of all the conditions under which he performed his work; hence, the analysis of all records in practice does not follow, but precedes, the determination as to whether the work was done well. The amount of work required is by no means large or prohibitive even for a small industrial plant, but the benefits derived from such close study, leading to continuous improvements and prevention in the very beginning of any deterioration of efficiency, are so large as to warrant the employment of a well-paid and highly-trained engineer, with a keen analytical mind. In our experience such scrutinizing and summing up of the day's log and other records usually takes but a small fraction of the time of a study-man or planning engineer. The balance of his time is utilized in further experimentations and training of help.

The analysis of records covering the conditions and results of operation gives the clue to the real mastering of power production. Opinion and judgment have no room or excuse since it is obvious that any guess not based on the positively established facts has at least as many chances to be false as to be right. When, however we take into consideration that in all guess work, opinions are formed not on the basis of all influential factors but on the most conspicuous ones only, it becomes evident that omission of one factor, or a wrong assumption of any, necessarily leads to a false conclusion. The empirical proof of this statement is obtained in every case where full records are not kept, or, if kept are not carefully studied.

In such plants a large margin for economy is invariably present. The author emphasized this fact at the annual meeting of The American Society of Mechanical Engineers in 1917 suggesting the estab-

lishment by the United States Fuel Administration of a priority ruling on coal deliveries to those concerns that have and use their records correctly. The United States Fuel Administration in a circular letter of June 12 admitted this viewpoint by announcing the appointment of inspectors for investigation of the operating efficiency of power plants. A new principle was hereby accepted, though not yet clearly formulated, that *the natural resources of the people may be entrusted only to those who know how to use them for the public*


FORM SAB360

11	3	1913
MONTH	DAY	YEAR

I HAVE INVESTIGATED AND REPORT BELOW THE CAUSE OF LOST BONUS

DEPT. Elect.

DISTR. W. R.

BY D. Pope ON JOB firing

CONDITION Leaky pipe between damper and draft gauge resulted in wrong adjustment of draft and poor combustion

RESPONSIBILITY IS ALLOCATED TO Maintenance Man

REMEDY ATTENDED TO BY ME Ordered repair complet 11-3-13

L. D. Port SIGNED

FIG. 97.—RESULT OF WORK REPORT TO INDIVIDUAL EMPLOYEE

Before an employee returns to work next day the results and quality of his work is figured out and, if below normal, cause of failure is ascertained. The man finds this slip in his card holder instead of a slip for secondary wage. If the cause of poor efficiency is allocated to another party or to Purchasing Dept. management, etc., a different colored slip is used to absolve the individual from responsibility.

benefit and can prove that they have that knowledge, while those who recklessly or selfishly waste the national wealth are denied the opportunity to benefit themselves at the expense of the people.

In practice, the task of analyzing data is preceded by two separate problems (1) *calculation* of ratios, efficiencies, losses, expenditures, etc., and (2) *presentation* of facts thus disclosed to the proper party in the proper form. Let us now briefly review these functions.

CALCULATION OF RECORDS

The calculation of data collected on various records should be done by one in close contact with the work and possessing an inti-

mate knowledge of processes, of significance of data, etc. If all this figuring is done in the office, the touch with conditions may be lost, meaning of certain factors misunderstood or overlooked and, above all, time will be lost, between an improper operation is disclosed, inquiry made, facts checked, explanation received, and final steps made to ameliorate the condition which should have been promptly and directly corrected as soon as noticed. The value of records will be still more greatly reduced if calculated by a mere clerk or, worse yet by a machine for final results alone frequently obscure the cause and render no opportunity to get at the bottom of the trouble.

If a man is frequently absent or is periodically missing his task, he must be interviewed at once in order to explain the bare fact of his absence or poor work and the cause thus disclosed is recorded for it is essential to know why such was the case. Records of such facts must be always amplified by reasons why. Similarly idleness of equipment records, to be of full value must be supplemented by reference to the cause. Performance records, perhaps more than any other, call for prompt and competent scrutiny as to complicated interplay of causes. In this way low efficiency of evaporation if merely recorded on a report is but a danger sign and it is the function of one who calculated this efficiency to find out whether it was due to poor maintenance of equipment, unsuitable fuel, irregularity in load, improper handling of fires, etc. In the latter case he should find out why the firing was done poorly. It might have been a consequence of wrong indication of instruments causing wrong adjustment of draft, etc., or it may be that the man was requested to work two shifts without relief, or a green fireman was on duty without instructor's help or anything else. Thus we have come again to the conclusion, that the inspector and instructor should be one person so far as possible if the best of results are to be had.

Inasmuch as a man of this type usually has not much time for desk work, calculation of records should be made as simple and quick a proposition as consistent with taking into account all contributing factors. Slide rule must take place of pad and pencil and specially laid-out diagrams and calculators to be preferred to both; yet there must be a caution since any short cuts jumping over intermediate results must be condemned as they are liable to obscure the important fact: at what stage the efficiency of the process falls below standard. If we could at one sitting of input against output read ultimate efficiency such device must be unconditionally condemned, because we must know individual effects of the quality of fuel,

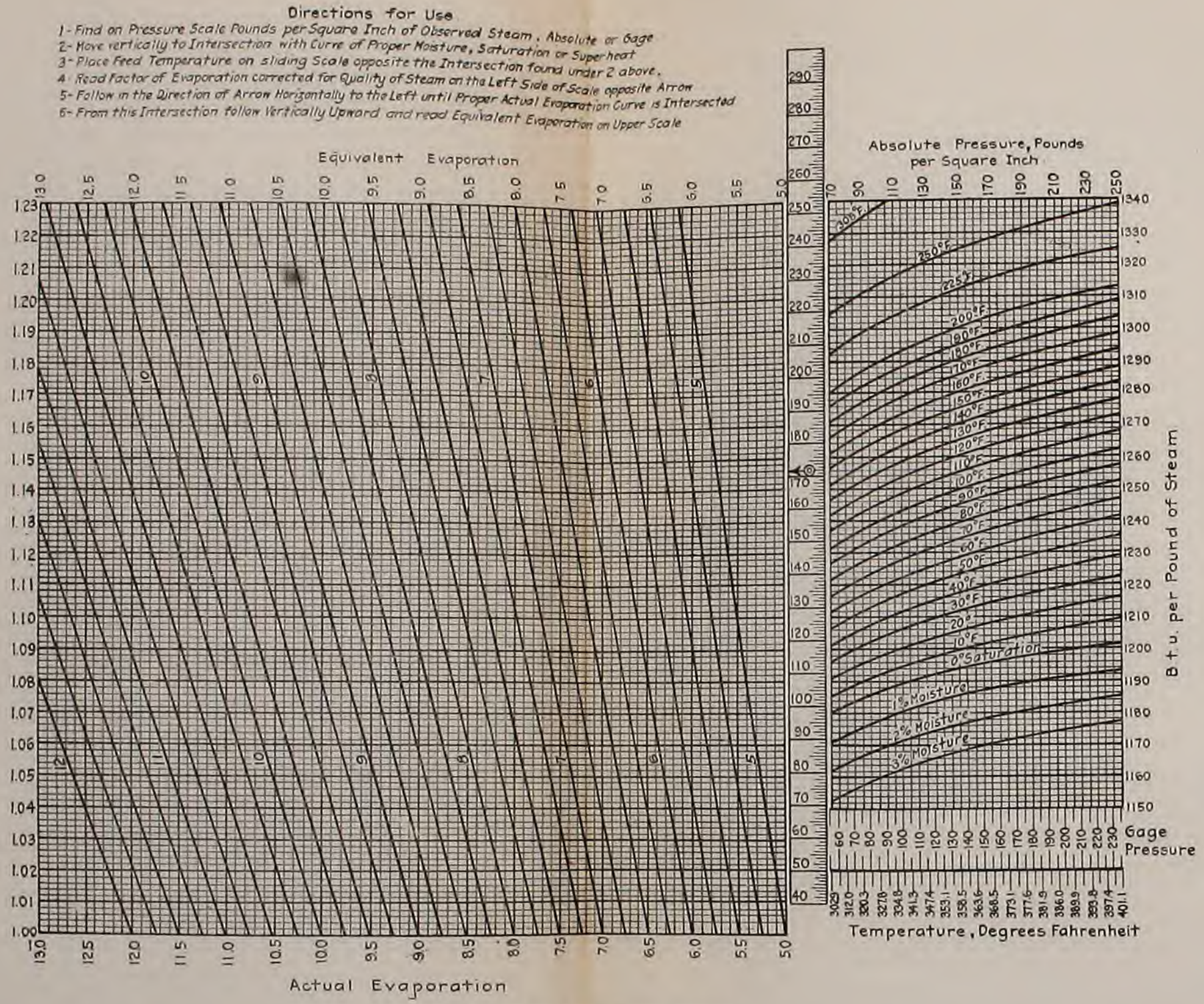


FIG. 98.—CALCULATING BOARD

This combination of two diagrams with a slide rule between gives at one setting the equivalent evaporation from known steam pressure, superheat, temperature of feed water and apparent evaporation, ratio of and equivalent evaooration.

temperature of feed, quality of steam and sometimes a few more things.

For the purpose of reducing the time consumed in calculations involved in summing up and determining efficiencies, various ratios,

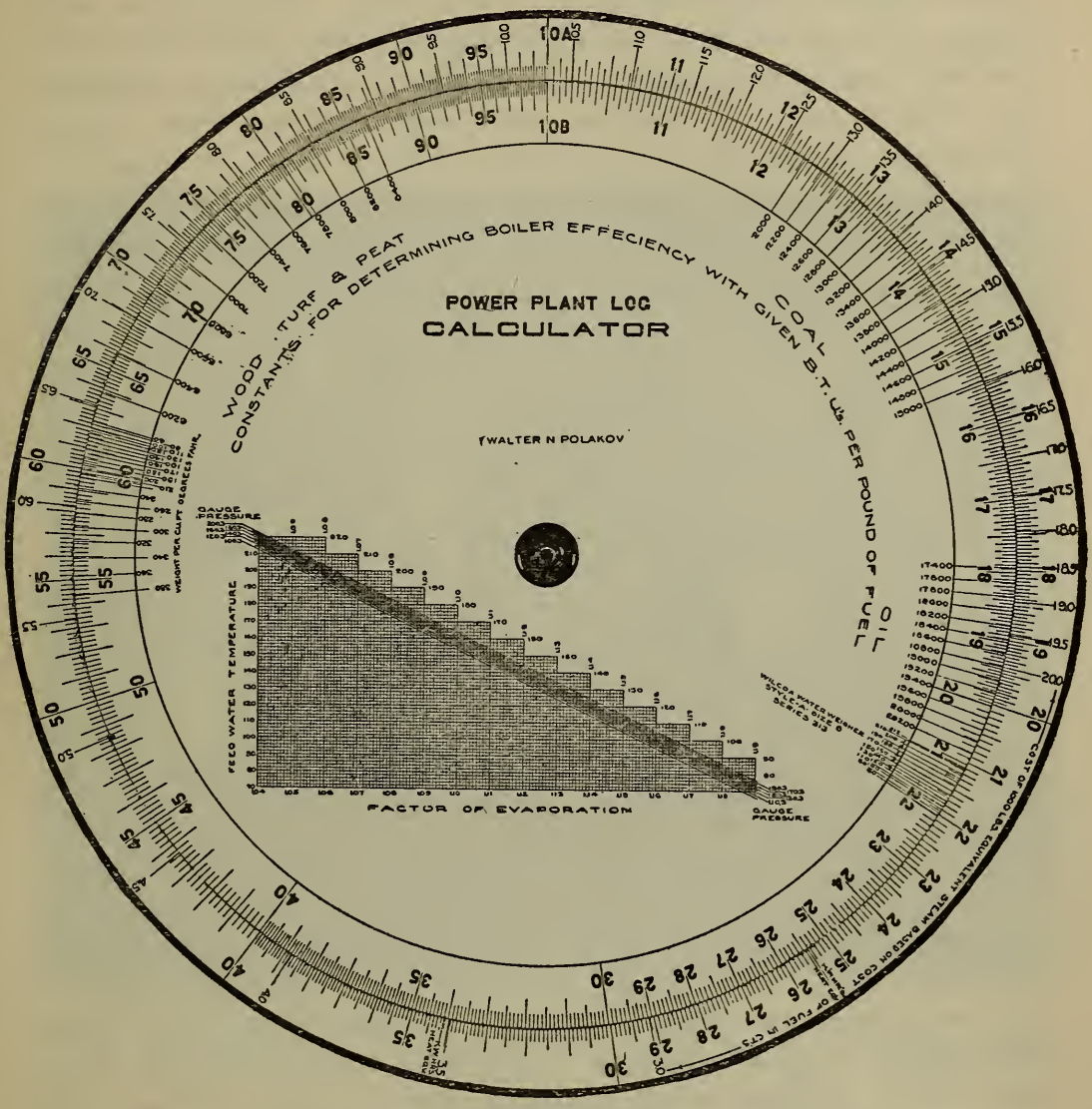


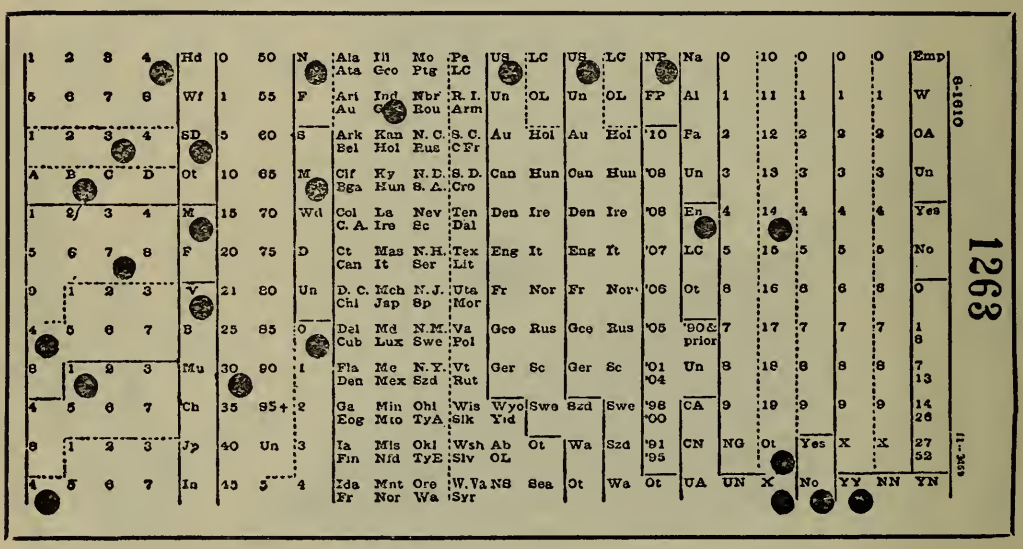
FIG. 99.—POWER PLANT LOG CALCULATOR

This device, copyrighted by the author in 1913, is laid out on logarithmic principle with several specific constants introduced. With its help all log data and daily performance report (as in Fig. 102) are calculated for three shifts in a few minutes without the aid of pencil, paper, slide rule, etc., with accuracy exceeding that of instrument readings themselves.

etc., and in order to avoid tedious and unreliable references to steam tables, a set of well-drawn diagrams or slide rule may easily be prepared. The use of such devices not only insures much greater speed, since a sufficiently correct interpolation can be made from a

conveniently plotted curve more quickly without the need of further figuring. The accuracy of the results is at least as high as that of the instruments furnishing the basic data.

The first example (see Figure 98) is a convenient combination of two diagrams, interconnected by a slide rule. The right-hand side diagram (based on Marks and Davis Steam Tables) has steam pressure and corresponding temperature as abscissa scale and as ordinate total heat in steam of different qualities as projected from curves. By setting opposite the ordinate scale of B. t. u. in one pound of steam the temperature of feed water, the factor of evaporation may be read on the ordinate scale of the left-hand diagram, opposite

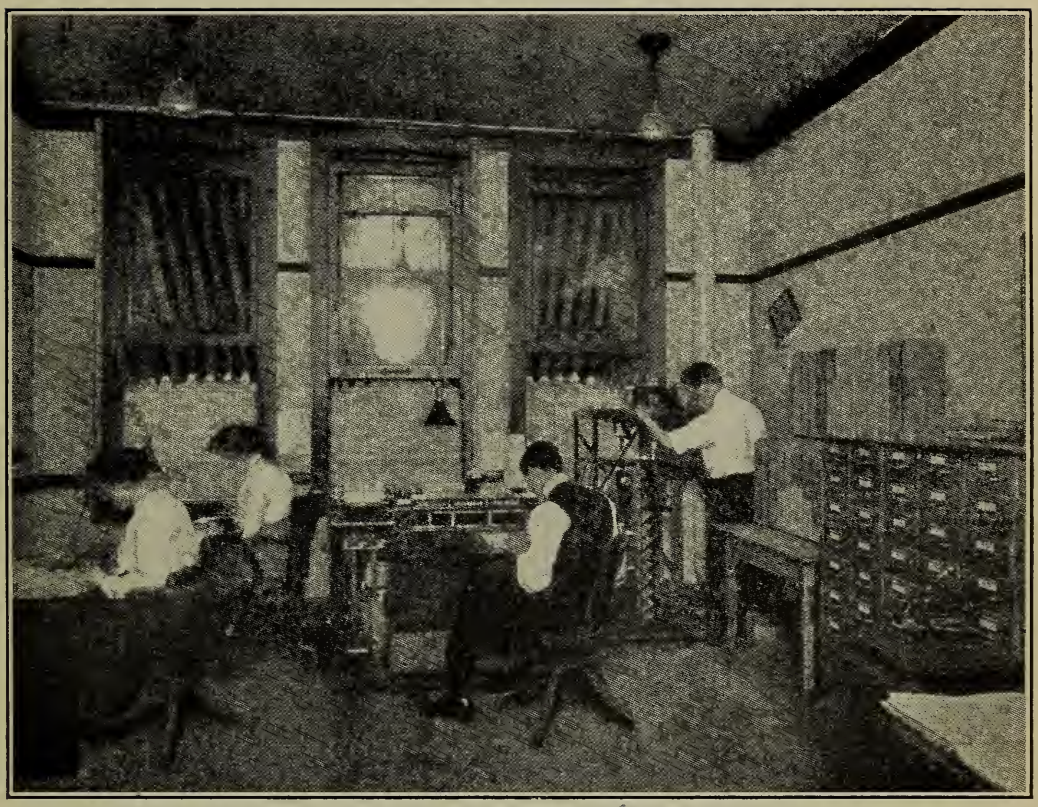


From "Graphic Methods for Presenting Facts" by Willard C. Brinton

FIG. 100.—HOLLERITH CARD AS USED FOR CLASSIFICATION OF EXPENSE DATA

the arrow-mark on the sliding scale (which in the setting illustrated is 1.146). With the aid of the left-hand diagram the equivalent evaporation per pound of fuel is determined by projecting from intersection of given apparent evaporation curve (diagonal line) with factor ordinate to the abscissa scale (on top). Thus with apparent evaporation of 1:8 and factor as set above the equivalent evaporation appears to be slightly less than 9.2 (9.168). The accuracy of such crude interpolation is as high as 99.66 per cent.

Another example of power-plant log calculator (see Figure 99) is based on a logarithmic principle with a number of useful constants introduced in laying out special scale. "The instrument consists of a logarithmically divided disk (inner scale) centrally revolving on a similarly divided dial (outer scale). The divisions are from 1 to 10 and any multiple of 10. Additional graduations are made for constants for the determination of the thermal efficiency when fuel



From "Graphic Methods for Presenting Facts" by Willard C. Brinton

FIG. 101.—MACHINE FOR CLASSIFICATION AND SORTING OF HOLLERITH CARDS

or different heat value is used. On the outer scale of the dial graduations are made which are constants for the determination of the

STRATHMORE PAPER COMPANY.

DAILY PERFORMANCE REPORT

MITTINEAGUE STEAM PLANT

3	20	18
Month	Day	Year

	1st Tour	2nd Tour	3rd Tour
Fireman on Duty	John Doe	Thomas Smith	Geo. King
Average Steam Pressure LBS. PER SQ. IN.	127	125	126
Temperature of Feed Water—F°	220	225	230
Factor of Evaporation	1.035	1.03	1.024
Coal Used (Total)—Lbs.	34,280	29,700	21,000
Coal Used (Banking Excluded)—Lbs.	34,200	28,500	20,400
Water Evaporated—Lbs.	311,000	261,500	188,000
Apparent Evaporation	9.10	9.18	9.23
Equivalent Evaporation	9.42	9.45	9.47
Efficiency of Steam Generation	73.7	74.0	74.4
Cost of Coal Per 1000 Lbs. Steam	27.5¢	27.4¢	27.3¢

Miscell.		
	Colorific Value of Coal—B. T. U. as Fired	11,600
	Ash—Laboratory Report—Wet Basis	16.5%
	Moisture—Coal as Fired—%	6.5%
	Coal Consumed Total—	Anth.— Bit.—

COAL STATEMENT

	Total	Anth.	Bit
TOTAL New Delivery	203,100	——	——
On Hand YESTERDAY 7A.M.	1,247,900		
TOTAL Consumed	84,980	67,984	16,996
Balance on Hand To-day 7A.M.	1,366,020		

Cost of Coal—Long Ton— Aver. B. T. U. Aver. Ash—

Remarks— STARTED #4 Boiler at 6 P.M. Load Extra Heavy

Signed E. S. T.

FIG. 102.—SHORT FORM OF A DAILY PERFORMANCE REPORT

In practice at times higher executives having no time to analyze power plant log are kept in touch with daily performance of each shift by means of such short summary.

cost of fuel for the generation of 1000 pounds of equivalent steam. They are based on the cost of 1,000,000 B. t. u. Equivalents for ready interpretation of horsepower and kilowatts in heat units and

cubic feet of water at various temperatures into pounds are also marked on the disk and dial. In the center of the disk is a diagram for the determination of the factor of evaporation for saturated dry steam. Instructions for the use of the chart follow:

"Weight of Feed Water—Set 10B opposite the Wilcox water-meter reading found on the dial. The result in pounds appears on the dial opposite the feed temperature marked on the disk.

"Cubic Feet into pounds—Set 10B opposite the number of cubic feet on the dial. The result in pounds appears on the dial opposite the observed temperature.

"Steam Consumption per Kilowatt-hour or Horsepower-hour—Set the kilowatts or horsepowers of output on the disk opposite the number of pounds of steam consumed, read on the dial. The result in pounds per kilowatt or horsepower-hour appears on the dial opposite 10B of the disk.

"Fuel per Unit of Output—same method as above.

"Actual Evaporation—Set the number of pounds of fuel, read on disk, opposite the number of pounds of water evaporated, on the dial. The result appears on the dial over 10B of the disk.

"Factor of Evaporation—Find feedwater temperature at the left of the diagram in the center of the chart and follow the horizontal line to its intersection with the diagonal line representing gage pressure; then follow the vertical line down and read the factor of evaporation at the bottom.

"Equivalent Evaporation—Set 10B of the disk opposite the factor of evaporation number on the dial. The result appears on the dial opposite the actual evaporation number on the disk.

"Efficiency of Boiler and Grate—Set the heat value factor (B. t. u. per pound of fuel) shown on the disk opposite 10A on the dial. The result appears on the dial opposite the equivalent evaporation number on the disk.

"Cost of 1000 pounds of Equivalent Steam—Set the observed efficiency number on the disk opposite the cost of 1,000,000 B. t. u. in the shape of fuel shown on the outer scale of the dial (which is designated for calculation of cost, but does not show the cost). The result appears in cents on the dial opposite 10B.

"Load Factor—Set the number of kilowatts in the peak power load on the disk opposite the number of average power read on the dial. The result appears on the dial opposite 10B.

"Thermal Efficiency of the Whole Plant—Set 10B of the disk opposite the constant for kilowatts or horsepower printed on dial. Note the point on the dial opposite the output number on the disk.

Set the disk's figure of pounds of fuel consumed under previously located point on dial opposite 10B. Set again the disk so that opposite the point thus found will be the number of B. t. u. per pound of fuel used. Do not use constants for the determination of boiler efficiency. The result appears on the dial opposite the 10B mark.

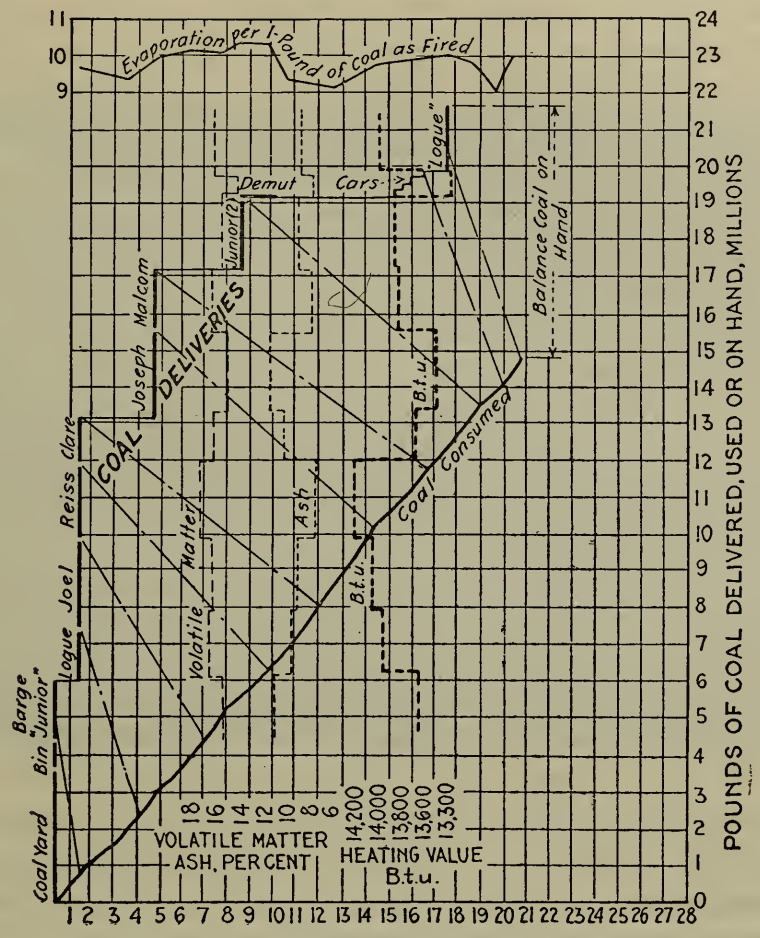


FIG. 103.—REPORT TO FUEL AGENT

This graphic report shows at a glance deliveries, their quality, their use, results secured, clearances from docks, RR. deliveries, coal analysis of every barge and for any day when coal was used, also balance on hand daily and at the end of the month. See text.

"Use as Slide Rule—Any multiplication can be made following the rule for determination of equivalent evaporation and division by following the rule for load factor. All these calculations and others not mentioned can be made quickly and accurately with the calculator."

PRESENTATION OF RECORDS

The presentation of the worked-out records offers special problems whose solution depends largely for whose use they are intended.

Data forwarded to cost and payroll clerks should be prepared in form of numerical tabulations or even in sorted packages of time cards and stores-issue cards. These may be in some specific cases, not of the usual kind described elsewhere in this book but in form of Hollerith cards (United States Census machine), properly punched to indicate district, purpose, charge symbol, date, nature of record, item, cost, amount, etc. (see Figure 100). Cards of this kind can be simply and quickly sorted, tabulated, etc., by means of machines (see Figure 101) but in all cases the responsible heads of departments must previously examine same to insure personal contact with all the little "shop incidents" as otherwise this intimate touch being lost in machine handling of human records, coöperation and personal relations can easily be impaired.

Most if not all records should be analyzed and examined daily to insure prevention of repetition of yesterday's mistakes or failures. Some of the summaries made for the information of officials higher up may be made weekly, provided the executives having direct charge and control over the particular phase of the work receive daily their detailed reports.

This log may be condensed and summarized on a short daily report form (see Figure 102) while the general storekeeper or purchasing agent will find adequate information in a chart sent to him weekly or even monthly (see Figure 103). The chief operating engineer will be benefited by having a board with adjustable strings pinned each day or every eight hours to represent the fluctuations and general trend of such operating factors in which he is particularly interested (see Figure 87). Men must by all means have easy and simple means of watching the records of their own progress. Sometimes a board is placed in a small power house to represent graphically efficiency of each shift for every day of the week, while Figure 104 gives a particularly interesting example and proof that the men, once in the game and realizing that upon their efficiency the happiness and welfare of the community largely depends, do not care even to wait for the bulletin board being filled—they keep their own score and draw in a chalk a diagram on the boiler front showing relative merits of their work. Note the mark "Shifts 1 and 2—tie" and try to get the psychologic meaning. Moreover, do not fail, in studying this photo to pay due attention to the method of graphic presentation used, which is accepted by us as the most simple, intelligible and obvious manner of presenting facts and scheduling jobs.

The charting method of presenting the most essential facts to

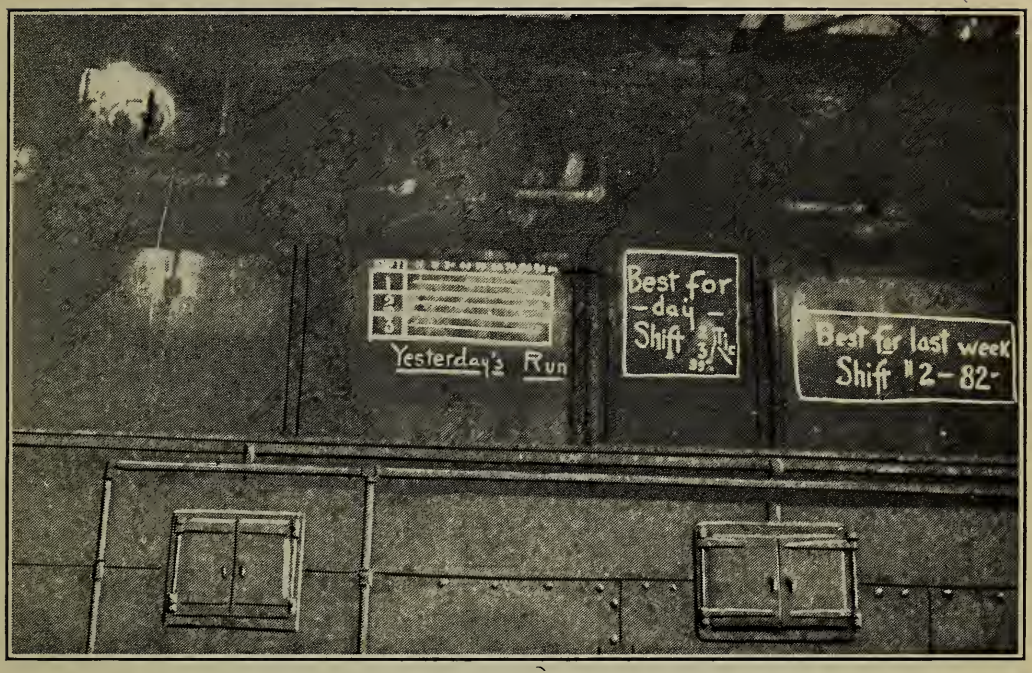


Fig. 104.—Who is Who in the Boiler Room

Diagrams like this on Fig. 107 are frequently drawn by firemen on the walls or boiler fronts to visualize their own accomplishments. It indicates that interest in the work is created and work has lost monotony since it is done with intelligence and sporting spirit. Base ball scores have less interest than these boiler room scores against the bogey—the length of the scale.

busy officials has proved to be the most satisfactory method. It answers our fundamental requirement that the records, to be of real value, must have a basis for comparison of what is done with what could and should have been done. It answers the demand that they should be easily comprehensive to the official as well as to the workman actually doing the work. It satisfies the demand that the cause of any loss is plainly allocated and finally it permits differentiation between losses due to poor management and those beyond the control of the management or men. For these reasons the claim is made that such *records are helpful for mastering power production* while a majority of other methods lead only to dissatisfaction or deception.

The three principal charts, picturing the operating progress and perfection in any plant are:

1 Equipment utilization chart
2 Fuel utilization chart
3 Skill utilization chart.

Below we give a brief description of each with reduced reproduction of sample charts:

Equipment Utilization Chart. This chart (see Figure 105) shows what percentage of plants capacity is used and what does it cost to have excessive equipment idle. Those familiar with Gantt's method of determination of the cost of idleness will at once note the similarity, yet the difference is profound and important. Power generating equipment differs from machine equipment in two respects: first, the output of the steam or electric generator depends on load or demand, rather than on time; second, the demand or load fluctuates within twenty-four hours irrespective of the planning of work in the plant. As a result of these peculiarities we must content with such a fact as peak and provide for it sufficient spare capacity which remains idle rest of the time unless the off-peak load is secured. In a purely lighting plant the idle time of equipment will be very large while in a power plant serving a manufacturing concern load may be so uniform that idle time is brought almost to zero. Again a break down of a machine tool in a group of several similar machines is not nearly as serious a matter as the disablement of a large electric generator or of one of the few boilers. The spare protective equipment, therefore, frequently constitutes a large proportion of the total installation and its idle time is an inevitable large burden. Finally, periodic overhauling and cleaning of power generating units is, as has been shown before of great importance

for the economy of operation and, if units are of comparatively large size and few in number, the portion of idle time due to maintenance is also considerable. On the other hand, such causes of idleness of equipment as lack of operators, lack of materials, etc., are practically non-existent in a power plant except in very extreme cases. The causes of idleness of power equipment are therefore analyzed usually only as to following:

1 Reserve for peaks

2 Reserve for break down

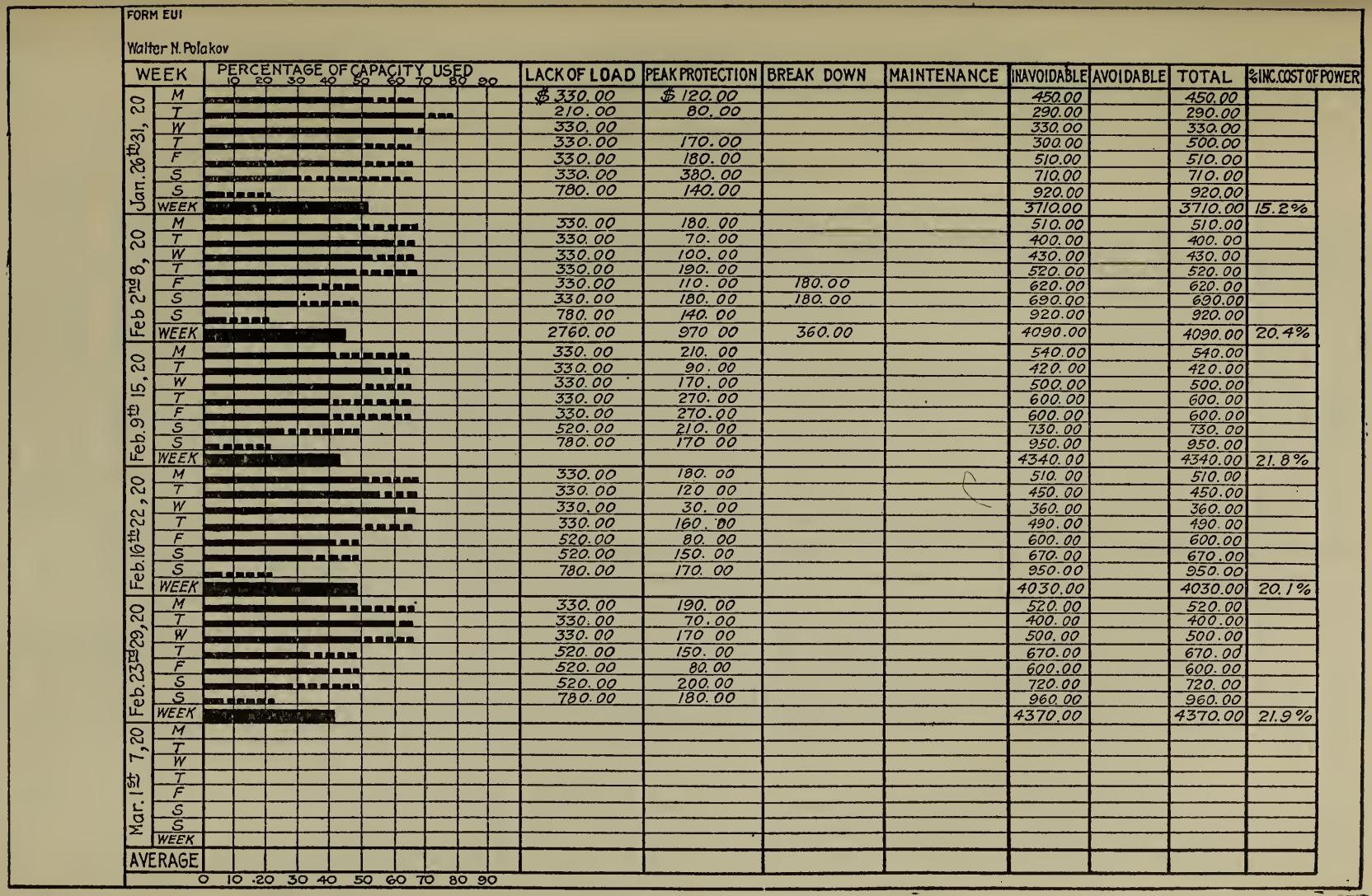
3 Reserve for maintenance

4 Lack of load.

In a factory power plant with usually uniform load throughout a day weekly or monthly total possible output of the equipment can easily be determined, and percentage for spare, based upon full available output, arrived at. Actual output for the period being short of that possible to satisfy, is shown as the percentage of plant equipment used while the balance is idle burden. More work for the factory, enlargement of manufacturing activity, extension of factory power consuming equipment or sale of excessive power generating equipment is indicated in cases of continuously high idle overhead on power equipment.

In a public utility central station the analysis is of necessity more complicated but the benefits derived therefrom are also greater. Charts of this kind should always be placed before the new business department to direct their efforts in proper direction and to warn them against securing loads tending to render operation unsafe or wasteful. A thorough study of such equipment utilization charts made by a number of plants in a locality would be invaluable, as indicating the lines of coöperation to mutual advantage with possible material benefit. It is important in such cases as the detailed analysis of the use of various classes of equipment within different plants throughout the year would clearly show, what the interconnection of idle and overloaded plants may accomplish. Small isolated plants should be equally profited by carrying out such studies as the results will plainly show possible merits of coöperation with central-station service, either throughout the year or during certain seasons. More detailed explanations as to keeping such records will be found in the chapter on Mastering Expenses.

Fuel Utilization Chart. This chart (see Figure 107) serves to show at a glance whether the fuel is being utilized to advantage and



FORM EUI

Walter N. Polakov

WEEK		PERCENTAGE OF CAPACITY USED (10 20 30 40 50 60 70 80 90)	LACK OF LOAD	PEAK PROTECTION	BREAK DOWN	MAINTENANCE	INAVOIDABLE	AVOIDABLE	TOTAL	% INC. COST OF POWER
Jan. 26th 31, 20	M		$ 330.00	$ 120.00			450.00		450.00	
	T		210.00	80.00			290.00		290.00	
	W		330.00				330.00		330.00	
	T		330.00	170.00			500.00		500.00	
	F		330.00	180.00			510.00		510.00	
	S		330.00	380.00			710.00		710.00	
	S		780.00	140.00			920.00		920.00	
	WEEK						3710.00		3710.00	15.2%
Feb 2nd 8, 20	M		330.00	180.00			510.00		510.00	
	T		330.00	70.00			400.00		400.00	
	W		330.00	100.00			430.00		430.00	
	T		330.00	190.00			520.00		520.00	
	F		330.00	110.00	180.00		620.00		620.00	
	S		330.00	180.00	180.00		690.00		690.00	
	S		780.00	140.00			920.00		920.00	
	WEEK		2760.00	970 00	360.00		4090.00		4090.00	20.4%
Feb. 9th 15, 20	M		330.00	210.00			540.00		540.00	
	T		330.00	90.00			420.00		420.00	
	W		330.00	170.00			500.00		500.00	
	T		330.00	270.00			600.00		600.00	
	F		330.00	270.00			600.00		600.00	
	S		520.00	210.00			730.00		730.00	
	S		780.00	170 00			950.00		950.00	
	WEEK						4340.00		4340.00	21.8%
Feb. 16th 22, 20	M		330.00	180.00			510.00		510.00	
	T		330.00	120 00			450.00		450.00	
	W		330.00	30.00			360.00		360.00	
	T		330.00	160.00			490.00		490.00	
	F		520.00	80.00			600.00		600.00	
	S		520.00	150.00			670.00		670.00	
	S		780.00	170.00			950.00		950.00	
	WEEK						4030.00		4030.00	20.1%
Feb. 23rd 29, 20	M		330.00	190.00			520.00		520.00	
	T		330.00	70.00			400.00		400.00	
	W		330.00	170 00			500.00		500.00	
	T		520.00	150.00			670.00		670.00	
	F		520.00	80.00			600.00		600.00	
	S		520.00	200.00			720.00		720.00	
	S		780.00	180.00			960.00		960.00	
	WEEK						4370.00		4370.00	21.9%
Mar. 1st 7, 20	M									
	T									
	W									
	T									
	F									
	S									
	S									
	WEEK									
AVERAGE		0 10 20 30 40 50 60 70 80 90								

FIG. 105.—EQUIPMENT UTILIZATION CHART

On the 100% scale, representing full working capacity (output) of the power equipment installed, the solid bars represent the proportion of actual output to full possible, while dashlines represent the spare reserve capacity to meet breakdown or extra demand. The expenses of non-use of the balance of equipment is shown in tabulation classified by the causes. Effect of idleness on the cost of production is shown in per cent in the last column.

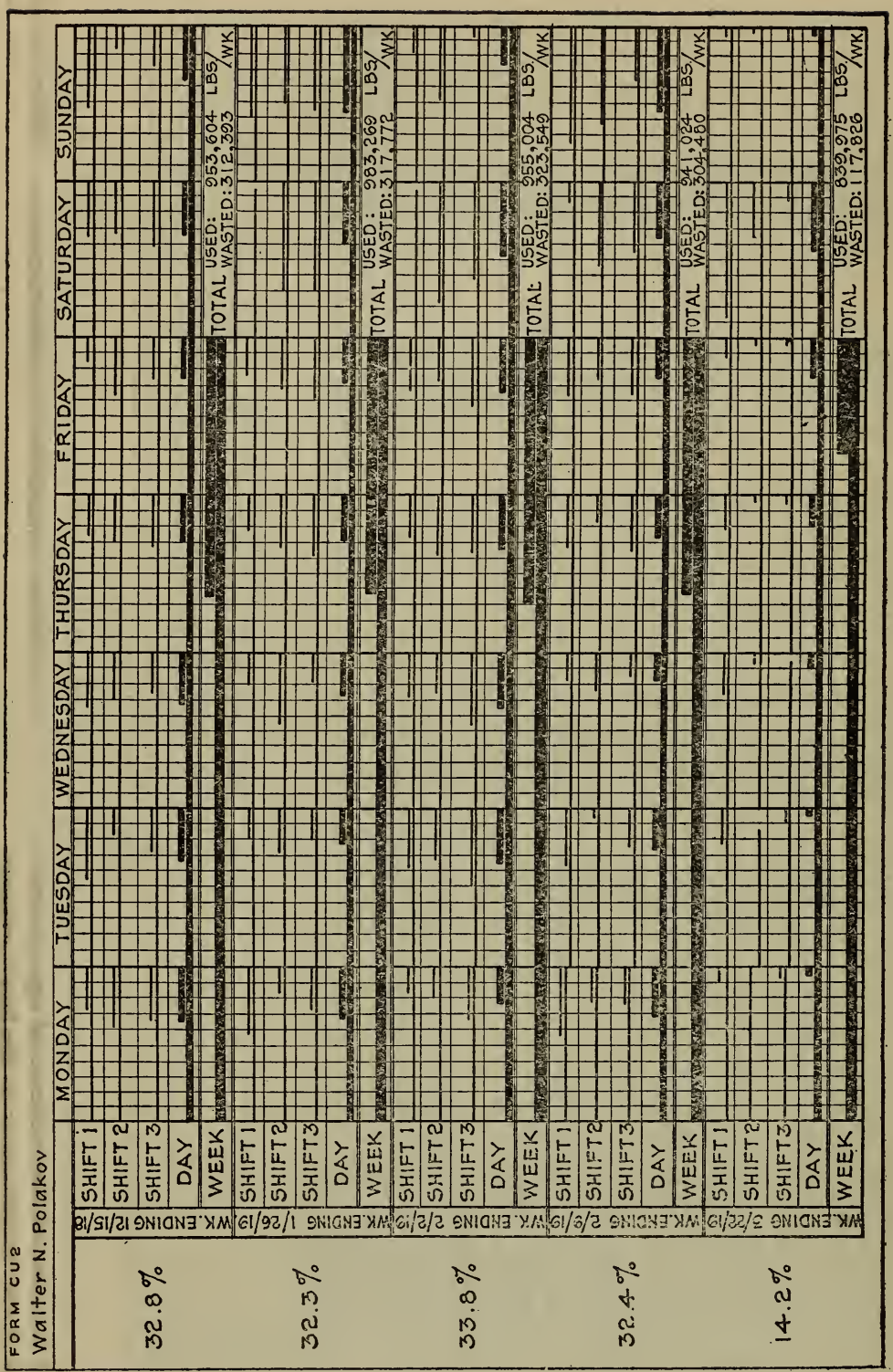


FIG. 106.—FUEL UTILIZATION CHART

Before the proper method of managing the plant and operating the boilers was inaugurated, excessive amount of coal was consumed as represented by doubled-up line of coal used. In this case a plant of about 3000 BHP. was wasting nearly ⅓ of coal (over 150 tons per week = $900). The improvement began to be noticeable during the last part of March when we started training of combustion engineers and firemen during our tests.

if in excess of reasonable amount—to what extent the loss is preventable. The general lay out of this chart is based on the same principle of comparison of what has been done with what should be. If in a given plant reasonable rate of evaporation is say 1 to 10 then on a day or watch when for instance 900,000 pounds of steam were gen-

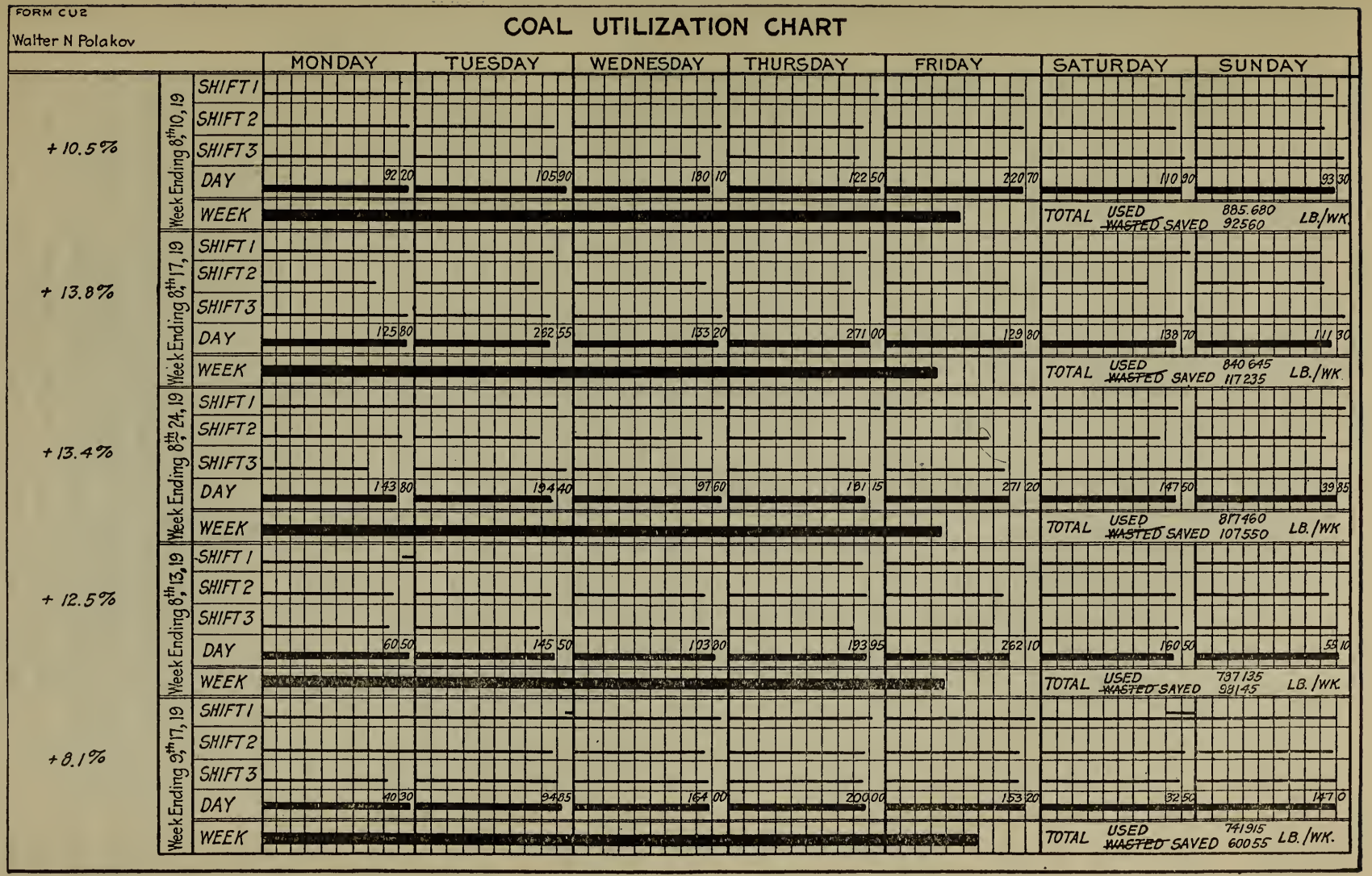


FIG. 107.—FUEL UTILIZATION CHART

This is the most fundamental record in power house. Full length of bar across the daily space indicates coal allowance for the load carried. Description in text. Compare with Fig. 105, where firemen keep similar chart on the boiler front for their own satisfaction.

erated, the reasonable fuel consumption should have been 90,000 pounds; if actually 100,000 pounds of coal was used the line will be 111 per cent of the space for the day, indicating 11.1 per cent incurred loss drawn as a second line on top.

The study of fuel utilization carried in this manner immediately attracts the attention of those in authority and invites further studies tending to disclose the means for elimination of losses. Charts of this nature carried even for a comparatively short time indicate as well the extent of the losses; in other words tell the executives how much effort and what expense are warranted for the elimination of the losses incurred. Several actual cases of studies conducted by such means are described elsewhere in this book.

Skill Utilization Chart. This chart (see Figure 108) is designed to represent visually the results of application of special skill by each member of the crew or each gang of men in securing the desired possible result on plant operation. In spaces provided for each man for each day lines are drawn to indicate that the work was performed for which wages were paid; if the work was of a quality equal or in excess of predetermined standard, a second heavy line is drawn on top of the other, indicating that extra skill was applied for which a secondary wage rate was paid. Should man be absent no line is being drawn, indicating that he failed to do his work. The top space over the graphic record space is provided for a suitable symbol denoting if a man failed to exercise required skill—the reason for such a failure, for instance:

f=fatigue

s=sickness

n=negligence

g=green operator

t=temporary or time work

x=cause not ascertained

z=absent,

etc.

Under this chart representing the exercise of skill by any group of men a curve may be drawn to advantage representing the fluctuation of efficiency in the particular process controlled or attended by the above group, thus establishing the relation between the exercise of extra skill and perfection of results attained. In case of payment of secondary wage-rate the chart shows who and when

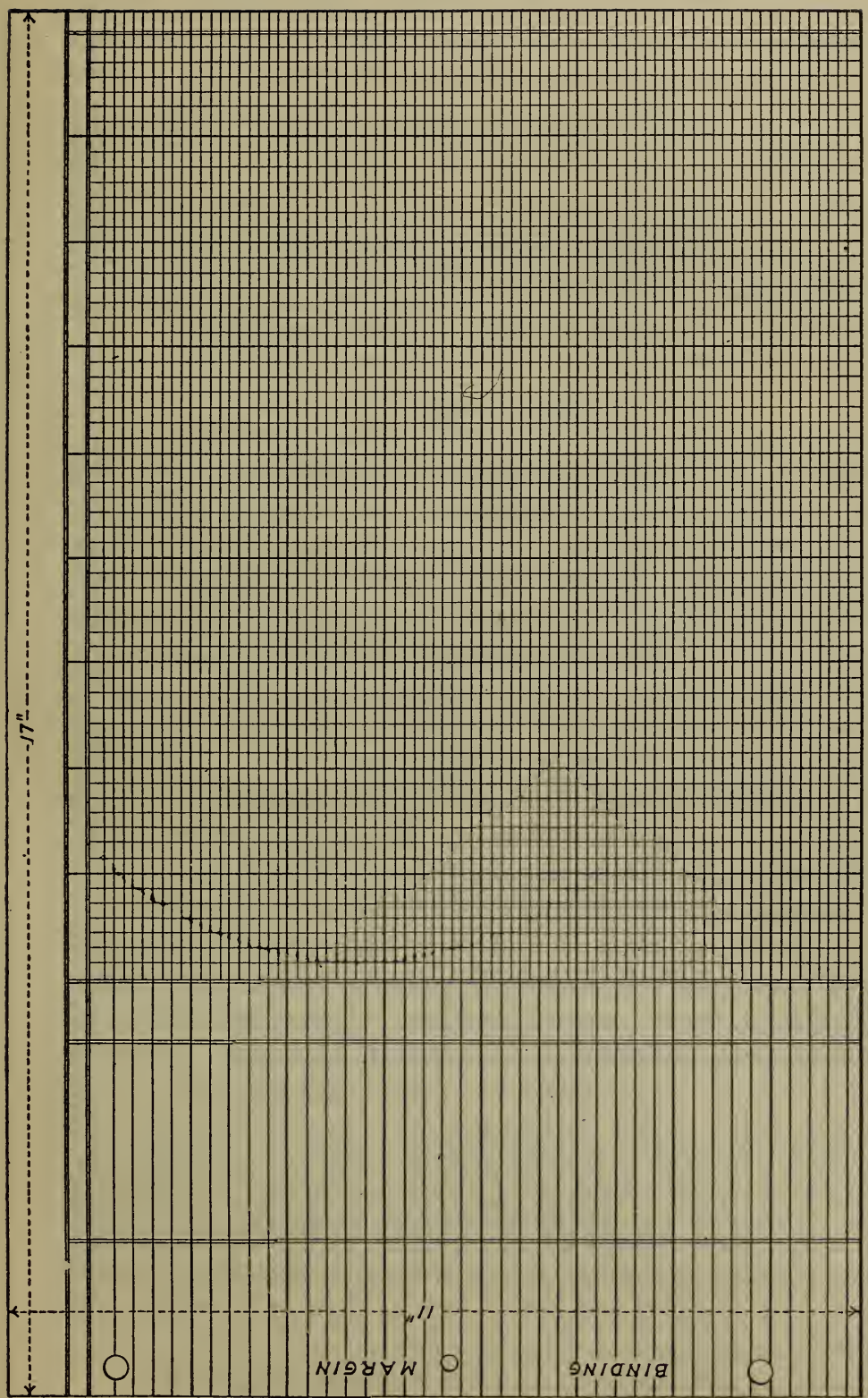


FIG. 108.—SKILL UTILIZATION CHART

This form is used to record performance of each man in the plant, showing for each day and week (vertical columns) opposite every name (horizontal divisions) whether a man was working, whether he earned secondary rate and causes of his absence or falling behind in the work, by means of symbols similar to those used on Figs. 73, 74, 77 and 82.

earned additional payment and in what relation savings accomplished stand to extra compensation earned. Finally study of letter symbols for each man and every day will direct attention of the executives to the most important causes standing in the way of the exercise of special skill. By proper measure harmful cause can be eliminated and the efficiency of men and processes brought to a desired high level.

Inasmuch as in every case the use of these graphic studies of the three main elements depends on the comparison of actual performance with the predetermined standard, careful study of possibilities in each case must be accurately made by a trained investigator.

Using Data

To sum up the foregoing outline of the essentials of plant records, we might say, without exaggeration, that the best methods of statistics as well as the most excellent records are of no avail unless proper use made of it. Men, machines, materials, and time have only potential value until they are put to some useful work. Most fertile soil produces but weeds unless cultivated. Similarly a collection of records is a dead ballast, or at best mere potentiality like a locked-up library until there is some one to study the significance of its contents and to make use of the knowledge gained.

The knowledge disclosed by facts on the record, like anything else may be put to a right as well as to a wrong purpose. In politics, secret diplomacy is becoming rapidly discredited as it leads to suspicion, conspiracies, defensive and offensive pacts, oppression and wars. A parallel situation is evident in industry. Men ignorant as to true facts in industry cannot be expected to act wisely neither in daily relations nor in cases of conflicts. Owners and their managers superficially informed do frequently base their policy on fallacies born out of prejudice or opinion instead of on actual facts. The public either tolerates service uncommensurate with compensation extracted or rebels against conditions of which they do not know the truth. Natural resources are wasted at a terrifying rate for the lack of knowledge or stimulus to change the routine. Industrial relations as well as future welfare of the commonwealth are in constant jeopardy because of lack of definite knowledge and secret facts.

The welfare and happiness of the community demands that:

1 The conduct of industry be based on facts, instead of opinions as has been too common in the past

2 Industry be placed in charge of men who are capable of understanding facts and of taking the proper action in accordance with them. Those who proved incapable should be dismissed or placed under a competent guidance.

To satisfy this requirement of wholesome evolution of our industrial life, the management, the workers and the community must base their action on facts and for that purpose the fundamental records should be available to all parties concerned.

The management will find proper guidance from such records in its task of

1 Rendering necessary service, that is, studying existing demand and providing for adequate supply.

2 Conserving human and natural resources, that is, studying existing practice, revising and improving same in order to eliminate all preventable wastes and losses

3 Rewarding service received, that is, studying service rendered by every number of the personnel, showing proper recognition of meritorious service and adequately rewarding for the value of service received.

The employees will find facts from complete records indispensable for:

1 Attaining results which are expected of them by management and by public

2 Securing skill through requests of instruction, help and assistance from management and experts, needed for attaining best results

3 Representation in management which, until the shop representatives or committee men, etc., are fully informed as to actual conditions is necessarily falling short of accomplishing their aims.

The public or rather the community served should similarly have access to the industrial records either through public service commissions or some other representation in order to know:

1 Whether necessary service is rendered or not; if not, why not?

2 Whether the service rendered is commensurate with the rates charged

3 Whether the conservation of natural resources is taken care of by maintaining highest possible efficiency.

Of these only the first two are so far within the scope of public utility commissions' functions, while the last, obviously the most important one from the viewpoint of the national welfare and the future of the country, receives no adequate attention. The rates for the service themselves could not be intelligently examined and adjusted unless the records of operating efficiency are the matter of public knowledge. A company using six pounds of coal per kilowatt hour may show a deficit on the balance sheet, but if its equipment, nature of service, etc., permit under better operating practice generation of one kilowatt hour with only three pounds of coal the petition for increase of rates should be taken with a grain of salt, for this possible saving of 50 per cent on the fuel bill may convert deficit into profit. In the author's memoranda to the Secretary of the Interior, dated July 28th, 1919, the following passage referred to this subject brought his favorable commend.

"Paradoxical as it may appear, it is nevertheless often true that a private company wasting fuel does not suffer appreciable loss thereby, and succeeds not only in transferring the expense of such waste to the public, but moreover, often charges the same public with the interest thereon. To illustrate without being specific, many public utility companies petition the public service commissions to permit the advance of rates for electricity or fares. The public service commissions, in granting such petitions, act *on the presumption* that the efficiency of plant operation in the plant concerned is as high as the state of the art permits, which in point of fact is far from being the case. The authorities should require, as a means of keeping in touch with actual progress of the elimination of this waste, a simple chart—to be kept and reported weekly or monthly to the power bureau—showing on a percentage scale the relations between the coal consumed and that allotted." (See Figure 107.)

According to the Division of Power Resources of the Geological Survey, all public utility power plants in the United States consumed on the average over 3.1 pounds of coal per kilowatt hour which means that the efficiency of this industry is less than 9 per cent and the preventable thermal losses alone are not less than 30 per cent. This means that the central stations of our public utilities waste $200,000 every day or nearly $75,000,000 a year over a modest actual standard of plants operated according to the principles advocated by us.

CHAPTER X

The Analysis of Expenses

ALL expenditures incurred in the manufacture of power are in the final analysis expenditures of human energy, both mental and muscular, exerted in the past, present, or to be exerted in the future. Natural resources, such as fuel, metals, and other materials while accumulated in the course of time by the nature are secured, worked out and applied through the human efforts. If the supply of fuel is exhausted the same should be substituted in some other way by the exercise of human efforts. Real estate, buildings, machinery, materials—everything entering or contributing to power production —is the creation of man and has value inasmuch as human life and energy worked into these things have themselves value. While the value of human life may be accepted as absolute and not subject to any graduation of individuals, the value of human efforts is relative and is commensurate with the service rendered. *Rewarding according to service rendered* appears to be the fundamental principle upon which our economic and industrial relations should be established and the discovery of a satisfactory method of measuring the value of service becomes our important problem.

The fetishism of money power is vanishing as rapidly as a clear conception is gained that it is the labor-power that produces all commodities and creates wealth. All the natural resources of a country are void of any value until the labor is applied to the resources and these are put to a definite use. Every commodity gets its value approximately in proportion with the time rate of labor-power expended for its production. In so far as money is a convenient equivalent of labor-power, the expenditure of money is commensurate with the expenditure of labor-power, and therefore excessive cost of production spells inefficiently applied labor. In other words, high cost of production is a result of waste. Waste of materials means waste of time and labor spent for mining, preparation and delivery of them even though it is reckoned in terms of money paid for misused materials. Similarly, use of a larger plant or machine than the output demands, represents the waste of labor-power originally required for its construction, etc., though such form of waste appears

to many as innocent as a sleeping babe. In this sense the over-expenditure of money is just as vicious a social crime as an arson, sabotage, lockout, or any other willful restriction of production—it destroys the productive efforts applied at one time or another or at least diverts or limits its application to some useless purpose. The old fallacy that one can spend his money as he pleases, does not hold any longer, since the money spent to no purpose means waste of natural resources and of social labor; similarly, the idle money means restricted production and limited satisfaction of wants and needs.*

Dwelling on this subject, Abraham Lincoln in 1847 wrote: "Upon this subject the habits of our whole species fall into three great classes—*useful labor, useless labor* and *idleness*. Of these, the first only is meritorious, and to it all the products of labor rightfully belong; but the two latter, while they exist, are heavy pensioners upon the first, robbing it of a large portion of its just rights. The only remedy for this is to drive, so far as possible, useless labor and idleness out of existence."

This viewpoint, unfortunately, is very often overlooked by those whose business it is to control the expenditures, and the common fallacy of the financiers at the beginning of this century was that the expenditures necessary for production were not separated from the useless expenditures of mismanagement and from idleness of the available means of production.

The task of mastering power production appears in this light as one aiming to drive out of existence (1) all useless labor, that is, labor either causing waste or applied to securing results that are ultimately rendered useless, and (2) idleness of men, machines and other means of production by setting both to some useful work. So long as we tolerate these conditions, the total amount of service rendered is far short of that possible, and the reward for service thus shared with waste and idleness is either insufficient or, if its share is made adequate, the burden imposed by these "heavy pensioners" becomes unbearable for the community receiving only limited service.

The fact that matter is neither created nor annihilated and that the energy merely changes its form in the universe may be of practical help to us only upon our attaining immortality. As long however as the years of our life are numbered, the water running over the

* Old saying "time is money" is not clear—the truth of this concept is better expressed by saying "money is time," i. e., money is a measure of time consumed in production of values. High cost indicates excessive time spent.

W. N. P.

dam and coal sending its heat up the chimney does concern us most vitally, as expenditures of such a nature cannot yield any return until this escaped energy may be worked up into a useable commodity. The analysis of expenses incurred in power production thus falls logically into dual inquiry:

1 Whether any use is made of the expenditure
2 Whether the results attained are commensurate with the expenditure.

Expenses and Cost

While it has been customary to appoint guardians for incompetent, minors and idiots and receiverships for business failing to meet their financial obligations, we were hitherto slow to realize the necessity of social control over undertakings producing dear commodities. It is obvious that a plant generating electricity which consumes twice the necessary amount of fuel has its bus-bar cost higher than it would have if properly managed; that the plant employing two twelve-hour shifts cannot secure the same economy as the one working three eight-hour shifts; and that the plant operating on full load only for short intervals consumes more steam and fuel and carries higher overhead charges per unit of output than one operated continually at a favorable load. Yet we insist that public service commissions should not interfere as long as the public gets satisfactory service at "reasonable" rates. This fatal misconception of what constitutes the cost of a commodity is primarily due to the above mentioned confusion of necessary and unnecessary expenses. As soon as a clear conception is gained as to what expenditures are actually necessary for an efficient production a distinction between the cost of production and expenses may be gained.

Let us take, for example a 50,000 kilowatt plant valued at $5,000,000 with actual output of 200,000,000 kilowatt hours per year, consuming 3.5 pounds of coal per kilowatt hour and reporting its expenses as follows:

Fuel	$1,050,000
Payroll	56,000
Supplies	6,000
Maintenance	72,000
Fixed charges	500,000
Administrative expenses	175,000
Total	$1,859,000

This plant is capable of safely producing 350,000,000 kilowatt hours per year using two pounds of the same coal per kilowatt hour, thus the output of the plant is only 57 per cent of its capacity. Yet its actual coal consumption would be sufficient to generate the full output. Its payroll, fixed charges, and administrative expenses will remain the same whether the ouput is 200 or 350 million kilowatt hours. In such a case the comparison of unit cost (in cents) per kilowatt hour would appear thus:

	On Limited Output	On Full Output
Fuel	0.525	0.300
Payroll	0.028	0.016
Supplies	0.003	0.002
Maintenance	0.036	0.021
Total operation	0.592	0.339
Fixed charges	0.250	0.143
Administration	0.088	0.050
Total production	0.930	0.532

Inasmuch as 15 per cent net saving on the fuel is entirely possible in this case 0.078 cent is unnecessarily spent on the production of each kilowatt hour, and neither the consumer nor the country gets any advantage therefrom. Furthermore, the fact that $675,000 is a necessary money outlay for the entire plant does not mean that the limited output should bear this entire charge while the customers get the benefit of only four-sevenths of the plant. The necessary expenses thus accrued, from which the public does not derive any benefit, appear as follows:

Waste of fuel	0.0078
Excessive plant	0.107
Pro rata of administration	0.038
Total waste expense per kilowatt hour, cents	0.223

The cost of each kilowatt hour, even for the 200,000,000 output, should be therefore but 0.930—0.223=0.707. In this case the expense is about 30 per cent higher than what the true cost of the commodity should be. If this obvious method of reasoning were laid as a basis for costkeeping, and the rate making or price

fixing recognizes the principle that the *consumer cannot be charged for all the expenses incurred by the manufacturer and his financiers,* the economic results would be beneficial for all concerned and far-reaching.

From this standpoint, the manufacturers of power, or any other commodity, have to accept the expenses of waste and idleness on their own account instead of forcing the consumer to pay for inefficiency of management or poor judgment or sometimes even future expectations from which no one but the investor himself expects the benefit.

The advantages derived from our plan are shared by both investors and consumers. An accurate knowledge of the excess of expenses over the necessary cost of production almost inevitably leads to the discovery of means for the elimination of this waste. Resulting possibility of reduced rates or selling price necessarily stimulates the demand for the commodity. Increased bulk of the output not only improves power factor, water-rate of turbines and all-around efficiency, but also absorbs the idle charges accumulating on the unutilized portion of the plant. Again, a larger output per unit of time means a more rapid turnover of the working capital and even a smaller rate of profit results in a larger amount of income per year. Increased bulk of net revenue in turn makes possible further betterment of plant and improvement of methods and, if the new demand due to reduced price of service is not yet satisfied, further enlargement of the plant capacity is possible.

The economists of Marxian school forecasted the abolition of private ownership of the means of production, among other reasons on the ground that the rate of profit falls as rapidly as automatic processes reduce the profit-yielding portion of the capital used to hire labor, were apparently supported in their premises by the entire economic trend of the past. This eventuality would have been realized before, were it not for the unprecedented increase of productivity with the limit of satisfied demand still beyond our horizon. Periodic business depressions, of course, signify merely a reduced purchasing power of society and in no way indicate that all individual wants and needs are fully satisfied or that no socially necessary production may further be expanded.

The significant feature of the old economic regime was the practice of producing commodities not at a cost, but at any cost and adding a profit on top of whatever expenses were incurred in production. At the same time the tendency of determining wages, that is, the purchasing power of the great majority of the consuming

population, was to keep them at the lowest level of the mere necessities of existence. It is obvious at the same time that *only the increase of efficiency of productive processes is capable of ultimately reducing the price of a commodity and increasing the earning power of the employees.*[115]

Any analysis of expenses would fail in its object if it does not thus differentiate the expenses as:

1 Productive expenses
2 Non-productive expenses
3 Idleness expenses.

Consequently the function of cost keeping cannot be properly carried out unless means are provided for such an analysis of expenses, that would clearly show what part of the expenses constitutes the cost of the commodity and what part of the expenses does not contribute anything to the value of the commodity, or to the value of the service rendered to the community.

While the truth and value of this conception has been accepted by leading engineers for some time past and elucidating testimonies have been made on the subject to the Federal Trade Commission,[116] the foremost accountants are gradually commencing to advocate this principle and to apply the same in their work. G. Carter Harrison, in his Cost Accounting to Aid Production [117] says:

"The far reaching consequences resulting from what Mr. Polakov calls 'this fatal misconception of what constitutes the cost of a commodity' are ably described . . . in that writer's article on 'Mastering Power Production' (*Industrial Management,* October, 1918, p. 321). It is beginning to be realized that the wasteful and inefficient manufacturer is not his own enemy solely, but that of his employees and of the community at large. In the long run the ultimate consumer pays for all material and human labor and is to this extent contributing to the high cost of living, and hastening the day of the exhaustion of natural resources.

"The obvious solution of the problem is, first, the determination of the necessary or standard cost of manufacture and, second, the separation of expenditures between those which are necessary and those which are the result of inefficiencies. As Mr. Polakov states: 'An accurate knowledge of the excess of expenses over the necessary cost of production leads almost inevitably to the discovery of a means for eliminating this waste.' "

It should not be inferred therefrom that an accountant, however able, can eliminate waste. It is decidedly an engineering problem but

an accountant can and should call attention to a loss. Neither can he do so unless an engineer, thoroughly familiar with the process, problems and probable location of waste, provides him with a suitable expense analysis plan or form.

Relation of Production and Cost

Progressive manufacturers, following the lead of Carnegie and Ford are trying to reduce manufacturing costs by means of increased production. Obviously enough, there are two ways of increasing the output of a plant. The one commonly recognized is through the increase of productivity of individual machines and men; the second, as yet not broadly accepted, is through pressing into work all the equipment at all times. "Mr. Carnegie realized that if he did not run his plants at all he would lose a large sum of money each year, and that he would be far better off to lose that money running his plant than to lose it if his plants were idle. His competitors preferred to close down their plants, with the result that they not only lost the money due to their idleness, but were not ready to take advantage of new business when it came." [118] Mr. Ford, likewise, concentrated his attention on the development of his plant management system on the basis that the productive capacity is constantly utilized.

Whether the work of these pioneers was prompted by proper light thrown on their expense analysis or whether they found a stimulus in the desire to control the market by offering goods at a lower price than their competitors knew how to do, is immaterial. The important lesson is that the lack of satisfactory cost system is one of the most serious handicaps in developing a sound industrial policy.

If the demand for the output is fairly constant from day to day throughout the year the ordinary cost accounting will show a fairly uniform unit cost of product. Its fluctuations will be due chiefly to a variation in the prices of materials and labor and to the methods of management in general. It will not however be able to give any idea as to how much more expensive is the product because the average output is below the full possible output. But if the fluctuations in the demand are considerable throughout the year or even within twenty-four hours, the conventional method of cost finding will be very seriously misleading, for the fixed portion of expenses will be at the times of large output spread over a large number of units, while at times when the demand is low it will make the cost appear much larger than if plant were utilized more fully.

These considerations are particularly important in application to power production, as most of the power plants, except those serving a large variety of customers with greatly diversified factors, have a seriously fluctuating output. In order to meet this rudimentary requirement of intelligent cost analysis, we must gain a clear conception how these fluctuations of output affect the expenses involved.

Assuming for the sake of simplicity, first a single-unit plant. Its operation involves four main groups of expenses:

Administration ..... a
Labor l
Materials ..... m
Fixed charges c
Total ..... e

Administration expenses, labor, and fixed charges remain constant whether the output is large or small and the unit cost therefore appears as a ratio of each:

$$\frac{a}{p};\ \frac{l}{p};\ \frac{c}{p} \text{ and } \frac{a}{p_1};\ \frac{l}{p_1};\ \frac{c}{p_1}$$

where p is the number of units produced and p^1 either larger or smaller. The use of materials, however, varies at once in double relation: to efficiency at various loads and to total consumption. Therefore if m/p is the unit cost of materials consumed in generation of say one kilowatt hour of electric energy, with a change of p the magnitude of this ratio will change not only in relation to output but the value of m itself will change—first, in relation to the efficiency of boilers, stokers, and turbines corresponding to their rate of driving, and second, as product of this efficiency and total quantity. With product p^1 the ratio m/p^1 will be not m/p^1 but m^1/p^1. Thus, for example the cost of fuel per kilowatt hour based on $4 per ton of coal of 13,000 B. t. u. per pound in a plant consisting of one boiler and one turbo-generator varied with load as follows:

Kilowatt Output per Hour	Boiler Efficiency, Per Cent	Cost per 1000 Pounds Steam, Cents	Turbine Water-rate, Pounds	Cost of Coal per Kilowatt Hour, Cents	Total Cost of Coal for Output, p, Dollars
250	60	24.8	37	0.9176	2.29
1000	74	20.0	19	0.3800	3.80
2500	72	20.7	15	0.3105	7.76

Assuming now a plant consisting of two or more units and the effect of the rate of production on expenses is beginning to be somewhat more complicated. So long as any unit remains idle it does not produce any power and to distribute the fixed charges of the entire plant over a partial output would mean a misrepresentation of true cost. Similarly administrative expenses do not change whether all units are working or not; the payroll generally remains constant although in some cases extra help is needed to carry the increased output. As regards the variable expense for materials (coal, water, etc.), while it varies substantially as illustrated in our first assumed case of single unit, the relation is more complicated both on account of distributing the load among units of the same characteristic, or probably among very dissimilar units as to their thermal efficiency and operating economy. For instance in a 5000 kilowatt plant the load of 3000 kilowatts may be shared between two 2500 kilowatt units as follows:

Unit No.	Case A			Case B		
	Load Kwh.	Water-rate Lbs./Kwh.	Total Steam, Pounds	Load Kwh.	Rate of Water Lbs./Kwh.	Total Steam, Pounds
1	2500	15	37,500	1500	17	25,500
2	500	23	11,500	1500	17	25,500
Total	3000	16.33 (aver.)	49,000	3000	17 (aver.)	51,000

Case B is obviously less economical, involving, due to characteristic of equipment, an unnecessary expenditure of a ton of coal every ten hours.

To give another illustration of the dependence of unnecessary expenses and losses from the rate of production, let us remember that when the power is generated it must often also be transformed prior to its distribution. Inasmuch as the efficiency of transformers ordinarily decreases rapidly at light loads below 50 per cent, due mostly to the core loss, it is very important to emphasize the economic importance of switching apparatus. A failure to at least disconnect large transformer installation from the line during idle hours when it is not possible to cut off the service at the station on account of power demands at other places on the line, would unnecessarily increase expense.

An illustrative example given by Mr. G. Roux, in the *General Electric Review,* for October, 1916, may be summarized as follows: comparing full-load operation during 24 hours with full-load during 4.8 hours and very small load during the remaining 19.2 hours, we obtain the following table:

	Full Load	Fractional Load
Output, kilowatts	4800	4800
Input, kilowatts	5347.16	5666.19
Efficiency, per cent	89.76	84.71
Losses, per cent	10.24	15.29

Three questions arise in this connection: who shall bear the burden of the losses; how to account for them; and how to avoid them. If the same output be distributed during the 24 hours, only one-fifth of the transformer capacity would suffice and, if such transformers were provided, they would not only greatly lessen the fixed charges on larger installation, but the losses would be reduced from 10.24 per cent to 5.03 per cent. In this case 319 kilowatt hours are lost daily, representing annually an unnecessary expense of not less than $600.

Again, if the capacity of a line is increased by the installation of a second line, that is, by nearly doubling the investment, instead of the installation of synchronous condensers to improve the voltage regulation at the receiver end (which as a rule, is a smaller investment) the question arises as to the proper charge for both losses on needless investment and losses due to wattless current, etc.

Such relations between the cost of service and the rate of production brings us face to face with another problem, the solution of which the cost accountant must submit to an engineer—namely to determine what is the necessary expense and what is the unnecessary.

In order to illustrate the fallacy of the tradition that the unit cost of producing power *decreases in the same proportion as the kilowatt-hour output increases,* we shall analyze here, very briefly, the variation of the unit cost of production for a 10 units 32,000 kilowatt-ampere power plant, assuming that a reasonable flexibility of the steam generating equipment exists, and that the efficiency of the management remains the same. Table 1, Figure 109, gives for this plant (for a range of output from 30 to 100 per cent of normal

rating) the variation in the unit and the total cost of the principal elements in production, as well as the unit and total cost of the entire production.

Representing the attached tabulated values graphically (see Figure 110), it will be noted that the total cost of production has been split into three main components, namely, (1) coal, (2) operating labor, and (3) maintenance labor and material and operating supplies except coal. It was observed within the range taken that the coal varied directly as to the output; that the operating

TABLE I—VARIATION IN COST OF PRODUCTION

% of Normal Plant Rating	Output in K. W. H.	Coal		Oper. Labor		Maintenance and Supplies		Total Production	
		Total Cost, Dollars	Unit Cost, Cents	Total Cost, Dollars	Unit Cost, Cents	Total Cost, Dollars	Unit Cost, Cents	Total Cost, Dollars	Unit Cost, Cents
30	856,000	3,070	.3575	1,400	.1640	806	.0940	5,276	.615
40	1,145,000	4,090	.3575	1,400	.1220	1,008	.0880	6,498	.573
50	1,430,000	5,110	.3575	1,400	.0978	1,174	.0812	7,684	.537
60	1,715,000	6,130	.3570	1,400	.0816	1,320	.0769	8,850	.516
70	2,000,000	7,150	.3575	1,400	.0700	1,450	.0725	10,000	.500
80	2,285,000	8,160	.3575	1,400	.0613	1,560	.0683	11,120	.486
90	2,570,000	9,180	.3575	1,400	.0545	1,660	.0646	12,240	.476
100	2,860,000	10,200	.3575	1,400	.0488	1,762	.0616	13,362	.466

FIG. 109

labor was constant and independent of the output; and that the maintenance expenses varied about one-half as fast as the output. The resultant curve showing the total unit cost of production indicates that for an increase in output of 234 per cent, the decrease in unit cost was only 24 per cent.

Inasmuch as the output of this plant for the year 1914 was 35 per cent greater than for the year 1913, the unit cost should have decreased 6.6 per cent, while as a matter of fact it actually decreased 15 per cent. Evidently this decrease was due to causes other than increase in output. Since there have been no physical improvements of any kind made at the plant during this time, the additional decrease over that which was to be expected is due purely to the human element, that is, to the improved methods of management.

Relation Between Efficiency and Cost

The relation between the efficiency and the cost must be established and understood before any attempt is made to control the production. Generally speaking the higher the thermal efficiency of a plant, the higher is the operating economy. This however may not always be true; while the same plant with other conditions remaining constant may secure a higher efficiency of some partial process the expenditures involved may exceed the advantages derived from the increased efficiency; again it may be found that a sacrifice of thermal efficiency may yield larger financial returns if a quicker turnover of the capital is thus secured. To illustrate: improvement of vacuum from 28 to 30 inches will require additional steam consumption by auxiliaries, an extra amount of water, and probably increased overhead charges on the improved equipment, all of which taken together would cost more than the value of steam. If the furnace efficiency is 75 per cent, say at 100 per cent rating, while at 150 per cent it may drop a few per cent, it may be found that the cost of the additional coal wasted is either smaller, equal or larger than the saving on rent, depreciation, interest, and payroll of the boiler plant which is to be enlarged 50 per cent, instead of carrying 50 per cent overload on existing equipment. In other words, the apparent advantages of low thermal efficiency are not real and are due only to our financial system which derives its benefit not from service to society but from destruction of natural resources as well. The same paradox is evident in the case of economy on wages. While the lower rates paid to employees or the longer hours they are compelled to work, reduces the total payroll and apparently increases the economy, they undermine eventually not only the prosperity of the nation by creating dissatisfaction, increasing the death rate, lowering the health standard, reducing the buying ability of the country, retarding the intellectual development, etc., but even affect immediately the concern practicing such form of economy. A low rate of wages attracts none but the poorest grade of help, long hours rapidly depreciate the physical and mental value of workers and the quick and inevitable result is low operating efficiency where increased cost of fuels offsets the savings on payroll, as well as greater liability for serious hazards.

In this case again the entire country pays with its man resources and its natural resources sacrificed for the sake of immediate concentration of gold in the hands of those practicing such methods. We thus arrive at the double conception of economy; individualistic

and social. While the individualistic conception of economy in production admits waste and losses as revenue producing means and thus introduces a conflict between economy and efficiency, the econ-

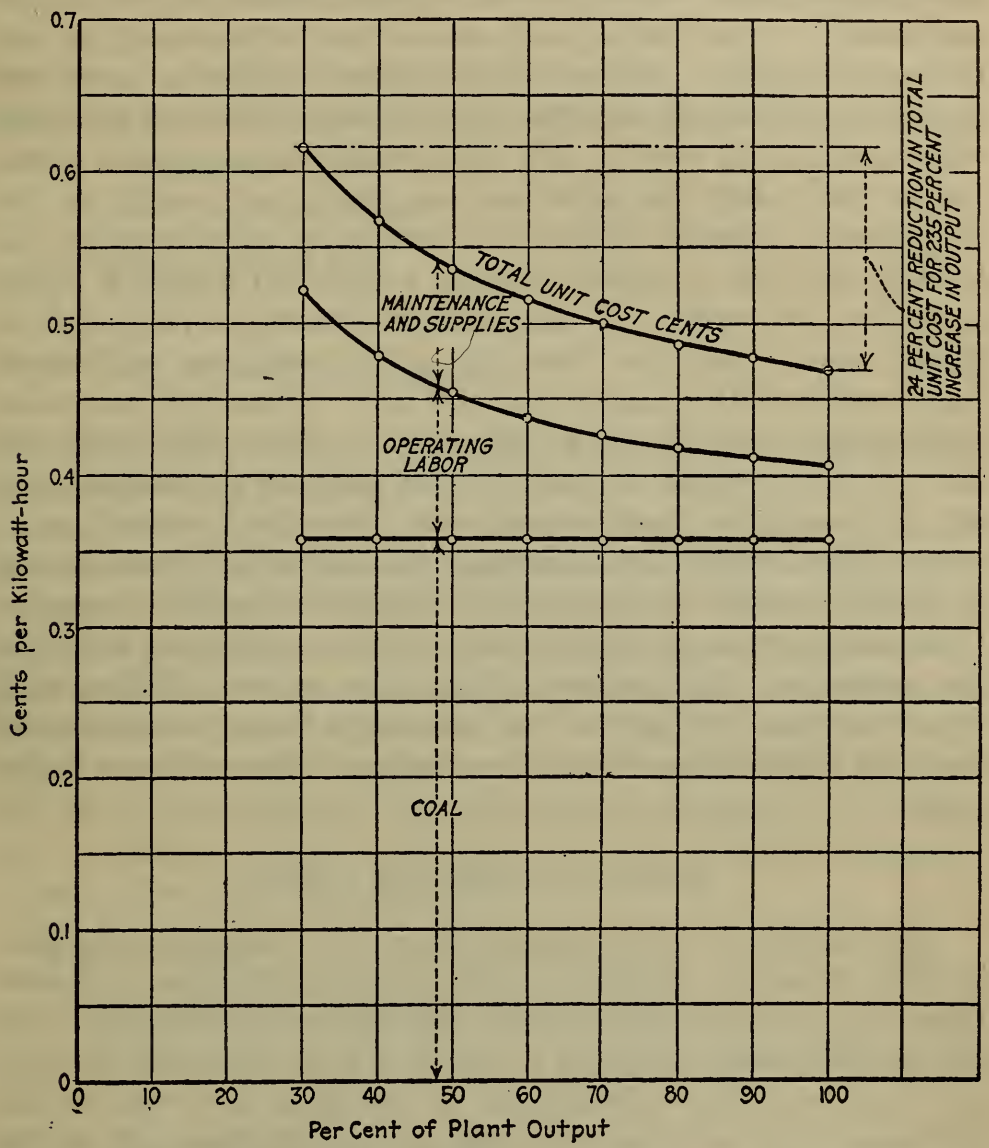


FIG. 110.—VARIATION IN TOTAL COST OF PRODUCTION WITH VARIABLE PLANT OUTPUT

Assuming that the thermal efficiency will be maintained at a uniform level, carrying any load from 30 to 100% of plant capacity, we see that with nearly trebled output the unit cost will be reduced only by one-quarter.

omy in its broad, national aspect explodes the paradox that it is profitable to waste labor and material since economy in the broad sense of the word is identical with the most efficient utilization of man power and resources.

As long as public service commissions aim to serve the interests

of the people they should not attempt to regulate the rates and the service rendered by the utility companies without examining the methods of power production and their effect on the cost. Moreover, inquiry into "reasonableness" of rates cannot be intelligently made unless a clear distinction is drawn between necessary and unnecessary expenses. Most of the prescribed methods of cost-keeping and accounting do not offer any opportunity for such important differentiation, but even if they did provide for segregation of expenses from which the public does not derive any benefit, the rest of expenses, ostensibly applied for production, transformation, distribution and sale of power may and actually do include a certain proportion of waste. To determine the extent of this waste of public money (paid for destroyed natural resources and wasted labor) and accurate measure it is necessary. It should be the task of public service commissions to determine for each utility plant and each district a schedule of standard costs based on the best engineering and managerial practice known and adjustable for any demand, output, price of labor and materials, etc., and to apply this measure to monthly analysis of cost reports submitted by utility companies. Until public service commissions are ready to render this service to the community which supports them, they are not fulfilling their duty, since their rulings are not necessarily based on indisputable facts, but largely rely upon the presentation of the case by conflicting parties.

Predetermination of Costs

At a meeting of The American Society of Mechanical Engineers in 1916, the author presented a paper on Standardization of Power-Plant Costs, since broadly quoted [119] but largely misunderstood. The aim was to present a method by which it may be possible to judge *how close the actual performance of the plant is to the possible minimum cost* at any time and under any circumstnaces, all variable factors beyond operating control being automatically adjusted. This possible minimum cost serves as a measure of economic perfection of operation. Obviously the physical, local, etc., dissimilarities of plants would not permit the adoption of a uniform scale applicable to each and every plant but for any particular plant, taking into account all its specific peculiarities it is feasible with comparative ease, to determine the individual standard of economic operation, which may be termed standard cost.

The cost of manufacturing power, or any other commodity, being the result of numerous factors involved in production, is in the

end the chief criterion upon which the market price, range of use, legislation, future developments, social welfare, etc., depend. Few if any of these questions can be intelligently answered from a knowledge of the actual expenses owing to the effect of an unknown factor —the degree of perfection of the actual performance. The importance of an accurate knowledge of the meaning and significance of actual cost data to the financier warrants the development of a method whereby a cost report tells:

1 What the power costs
2 What it should cost
3 Where the loss has occurred
4 Why the loss has occurred.

These questions answered, elimination of waste is a comparatively simple engineering problem.

Standardization and predetermination of the cost of power production have never before been considered as possible undertakings, and their advantages were thought questionable. Predetermination of operating costs has not been made use for other than estimates of probable future expenses prepared by promoters or contractors. These estimates are usually based, as is always the case in work of such a nature, either on past performances modified by expectations, or on data obtained from the actual performance of another plant considered as similar. The accuracy of such estimates depends at least on the following conditions:

1 How reliable were the cost records used
2 How near the possibilities were realized
3 How close is the similarity of the equipment of the plants under consideration
4 What effect has the location
5 What effect has the nature of load
6 What effect does the labor condition produce
7 How completely were the future factors foreseen.

However, since there is no assurance that in the sample plant the operating methods are perfect, it is not reasonable to expect that another plant is in every respect identical to the sample plant, and the value of such a guess of operating cost is highly problematical.

On the other hand, realizing that such estimates are inevitably

colored by the personal sympathies and prejudices of the estimator, a demand for a class of disinterested counsellors has been created. As the financial and not the thermodynamic side of the question is more vital to the investors, the predetermination of the results of power production is often entrusted to public accountants who may or may not be fully equipped to account thoroughly for the influence of such factors as the chemical and the physical properties of available fuels on the efficiency of boilers and furnaces, the effect of load and machine factors, water rate of turbines under the predominating condition of load, role of power factor, wattless current, phenomena of electric transformation, transmission, drop of voltage in distributing lines, and numberless other factors affecting the cost of current either directly or indirectly.

The urgent need of a dependable measure for the financial efficiency of operation has prompted managers and owners to compare their operating-cost data with those available from other plants. An attempt to decide whether one's operation is as economical as possible by comparing it with operating data from other plants whose equipment and service are more or less radically different, would be absurd were it not for the want of a better method. Table 2, Figure 118, presents an example of such an effort to make use of cost data by comparing the monthly cost reports of seven central stations. Their equipments are widely different; no two of them use the same grade of coal; the arrangement of machinery requires in some cases double the number of attendants: one is generating electric current for a trunk railroad, whereas others supply suburban and tunnel traffic or even private consumers, with consequent differences in the characteristics of current, distribution of load and peaks during the day, etc. Under such circumstances, to say from those data that one is operating more efficiently than another is, at least, too presumptuous.

The most interesting attempt to devise means for more rational cost studies was offered by Messrs. H. G. Stott and W. S. Gorsuch (*Transactions,* American Institute of Electrical Engineers, 1913). The use however of various factors tending to compensate for differences in fuel, load factor, labor cost, etc., is evidently inadequate. Prices per heat unit in the fuel, if adjusted, do not distinguish the differences in cost between the inherent efficiency of the boilers, furnaces, and stokers and the methods of firing or the personal element of attendance. The effect of load-factor corrections is entirely offset by existing differences in the water rates of the turbines and the influences of the auxiliary apparatus in the plants under comparison. Establishing payroll correction factors

on the basis of mere pay rates is erroneous, because of the size of units, floor plans, automatization of certain operations, etc., requiring more or less men, not to mention the fact that generally low pay to attendants results in high cost per kilowatt-hour, usually on the coal item and often in maintenance. Even if these factors of correction were unquestionably correct, this method leaves the effect of the supremacy of the equipment efficiency unseparated from the efficiency of the methods of management. Finally, even if all factors are fully accounted for, *the fact that one plant is as economical as another does not tell how far each of them is from its possible degree of perfection.*

Expenses that are independent of the volume of output are at the same time independent of each other and do not characterize the efficiency of processes performed in the power plant. Their effect on the unit cost is represented by a parabolic curve decreasing with the increase of output. They are exemplified by interest on investment, depreciation, sinking fund, insurance, management, payroll (in some cases), taxes, etc.

Expenses that vary with the output of the plant characterize the efficiency of operation, other conditions being constant, and their elements stand together in dependent sequence. If represented graphically, they show very irregularly shaped curves peculiar to each set of equipment. The unit has a general tendency to drop with increase of output, as the efficiencies of boilers, turbines, etc., tend to improve with increased load; yet, since with higher degrees of overload the efficiency decreases, the unit cost rises. With further increase of load, when an additional unit is started, the efficiency at first drops, then again begins to improve until their cumulative efficient capacity is exceeded, when the unit cost commences to again increase. Such waves are sometimes very pronounced, and generally, throughout the range of the plant's capacity, the number of waves on the unit-cost curves is equal to the number of generating units installed. Fuel, water, certain supplies, and, in less pronounced dependence, maintenance expenses, belong to this group of expenses, and to classify the expense account it is best to itemize them to correspond with the steps in which the energy is transformed during the generating process.

The criterion of economy is established by the interplay of three factors, time, product, and cost. When only one factor varies, its effect on the economy can easily be foreseen. Thus a greater product, without a change of the time required or the cost, increases the economy. An increase of either the time of production or the cost

of production reduces the economy. Generally, however, all the factors vary simultaneously, in which case an analysis of the equation for the economy criterion $\theta = \frac{P}{ct}$ can be made for any influential element n, and the increase of economy for a unit increase of n, if differentiated, is $\frac{P}{ct} = \frac{P'n}{P} + \frac{C'n}{C} + \frac{t'n}{t}$, all elements being essentially positive.

Such a general study can be made with respect to economy if more than one influential element is involved by means of simultaneous equations for each. The graphic method offers, however, an easier means of solving the problem. To determine the economic limit reached by a continuous increase or decrease of the influential elements is not an easy problem, but unless it is solved we are in the dark not only as to what economy can be obtained, but also what changes in conditions and methods are essential to attain the desired degree of economy. The analysis of the effect of the variations of these elements, involved in determining the maximum limit of economy and corresponding standard cost, can be compared to a determination of the height of the apex of a hill by taking altitude readings on both slopes in one direction and then repeating observations in the crosswise direction.

It is relatively unimportant whether the maximum limit of economy is determined empirically by rigorous observations, tests and analysis of all influential elements, or calculated from the principal data already available. It is however imperative that such a study be made and the economy limit established, as this is the only criterion for judging the actual performance. Carrying out the analysis of the economy limit to its logical conclusion, the standard cost of the product is arrived at, and evidently during this investigation not only are the itemized costs of the individual partial processes found, but the conditions and methods whereby the standard cost can be attained are established. In other words, *unless the standard costs are established an accountant has no measure of the existing losses.*

Manifestly, in the course of determining the standard operating costs, such factors as the inherent efficiency of the equipment, its efficiency under different loads, the prices of fuel and supplies, the necessary and sufficient number of attendants and their compensation, etc., are already taken into consideration for a given plant. Any deviation occurring between the actual operating cost and this standard cost indicates that some of the necessary conditions were not lived up to, and, if standardization has been carried out in

sufficient detail, it leads directly to the allocation of the loss to operating methods. On the other hand, any change in the basic data used in determining the standard cost being known, an adjustment of the standard cost can easily be made before the blame is put at the door of the operators. The efficiency of the thermo-

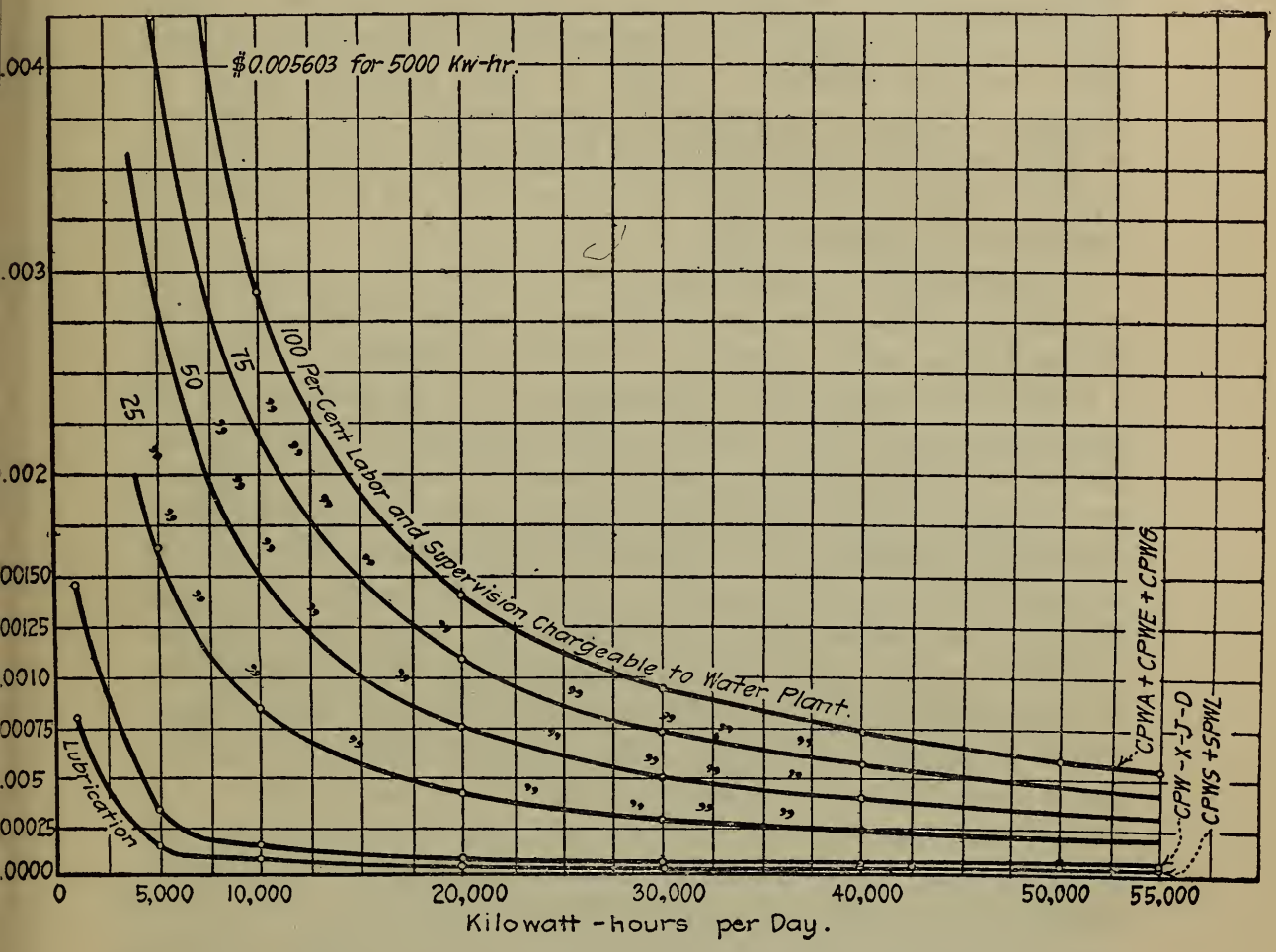


FIG. 111.—CURVES OF STANDARD OPERATING COST FOR HYDRO-ELECTRIC PLANT

Per cent of labor and supervision chargeable to hydro-electric operation is the same as the per cent of its output to total station output. Carbo-electric standard cost is shown in Fig. 113.

dynamic process so largely determines the operating cost in a power plant, that it should be made a subject of a most thorough investigation to ascertain first the maximum efficiency limit of each partial process, and then the result of their interplay. When this is accomplished, the entire process should then be studied for the purpose of standardizing the methods and adjusting for such a balance of the efficiencies of the partial processes as will secure the maximum

profit or economy for the time, energy and materials expended. In this it is sometimes found that the most economical thermal efficiency is somewhat below the maximum obtainable, as the slight additional gain in efficiency necessary to reach the maximum is not warranted by the expenditure required to attain it. When these limiting conditions are determined, a method can be defined for each member of the working force, prescribing his duties and the conditions he must maintain to secure the most profitable degree of efficiency. Upon the conclusion of these studies, the best efficiency of each unit and their combination being known for any load, the standard cost for any output in a given time can be conveniently represented in graphical form.

The principles of determining the standard cost of maintenance and upkeep of the plant and equipment are substantially the same; the method of study, however, is somewhat different. It involves a study of the design and construction of all the elements of the equipment; and minute records of their service and cost of maintenance which may lead to a modification of design, use of cheaper renewable parts, etc. Next, the standardization of supplies, beginning in the laboratory and followed by actual service tests, helps to determine not the lowest purchase price but the lowest service cost. Finally, time studies embracing schedules for inspection, routes for maintenance men, standardization of tools, motions, methods, etc., conclude the investigation. The criterion is, of course, not the wages of the employees, but freedom from accidents, breakdowns and the lowest attainable cost of upkeep per unit of the plants output. It is evident that there may not be any theoretically certain standard cost of maintenance, but an empirical standard thus developed is generally but a fraction of the best actual records of the past.

Upon concluding this double analysis of the maximum economy obtainable, the graphs of the standard cost of the power production may be drawn. Curves may be conveniently arranged with the coordinates of cost C and product per unit of time $\frac{P}{t}$ (output). It will then be noticed that the time element is one of the most influential factors in power economy. Whereas in some cases, where the number of generating units is large, the coal rate per unit of output remains fairly constant and the other items of cost reduce rapidly with increased production per unit of time, in other cases the standard cost of fuel also decreases as the time during which a certain output is produced is shortened. Figures 111 and 112 represent curves of standard operating costs. It is evident that any number of curves

may be plotted following the above method, each curve representing an itemized standard cost according to the adopted classification. Figure 113 is thus prepared for a medium-size public-utility central station. It shows the variations of the standard costs of coal, boiler-room labor, water, supplies, overhead charges, engineers and supervision per kilowatt hour at various monthly outputs. The cost scale does not show, however, the actual standard. This plant comprises four 600 horse power boilers and three turbo-generators, one

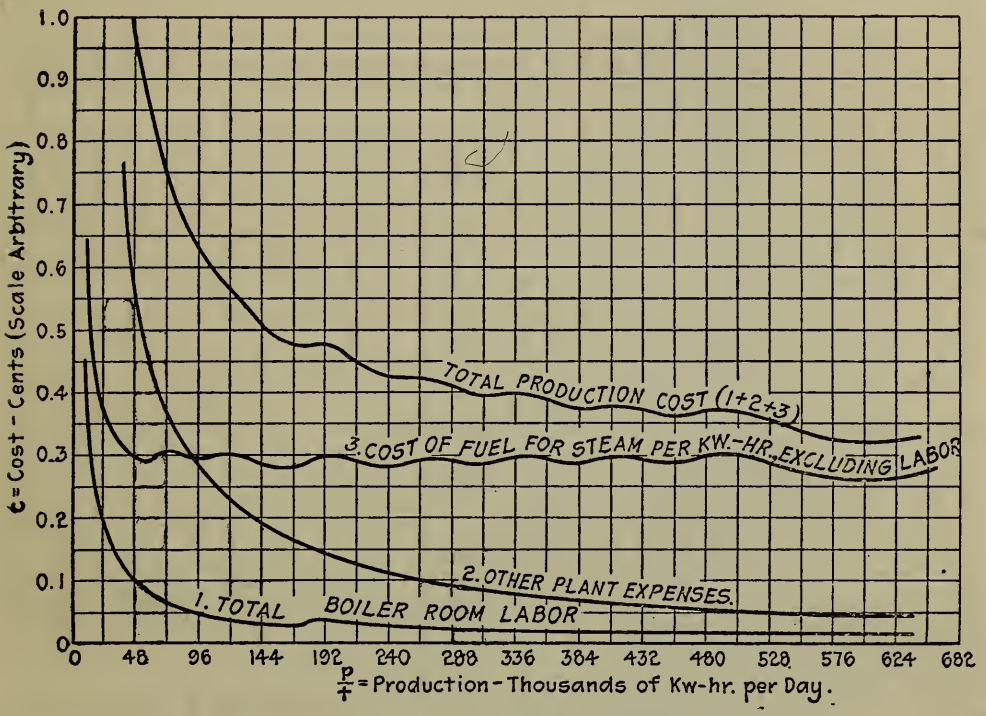


FIG. 112.—STANDARD OPERATING COST CURVES

This diagram was prepared for the year 1914–1915 for a large Electric Railroad Central Station, representing fluctuations in the cost depending on the distribution of load among generating units and general downward trend with increased production. The drop in the boiler room labor expenses below 190,000 Kwh. output per day, is due to idleness of the entire section of the Boiler House.

of 2500 kilowatt-amperes and two of 500 kilowatt-amperes; it operates 24 hours per day, 7 days a week.

From this diagram it appears that the cost of coal per kilowatt-hour is lowest when the output of the plant is approximately 1,900,000 kilowatt hours per month. Further increase of output coincides with the increased cost for fuel required, due to the characteristic of boilers and turbines that they lose in their efficiency at higher rates of driving. Again, costs of labor, supplies, prorated overhead charges, etc., per kilowatt-hour, which drop more rapidly than the cost of fuel rises, offset the difference and render a greater

monthly output more desirable economically. Even there, however, we meet a limit when at the rate of 2,000,000 kilowatt hours per month the unit cost becomes higher than it was at the lower output of 1,900,000 kilowatt hours per month.

Figure 112 illustrates a few characteristic curves of the standard cost kilowatt-hour for various rates of output of a large central

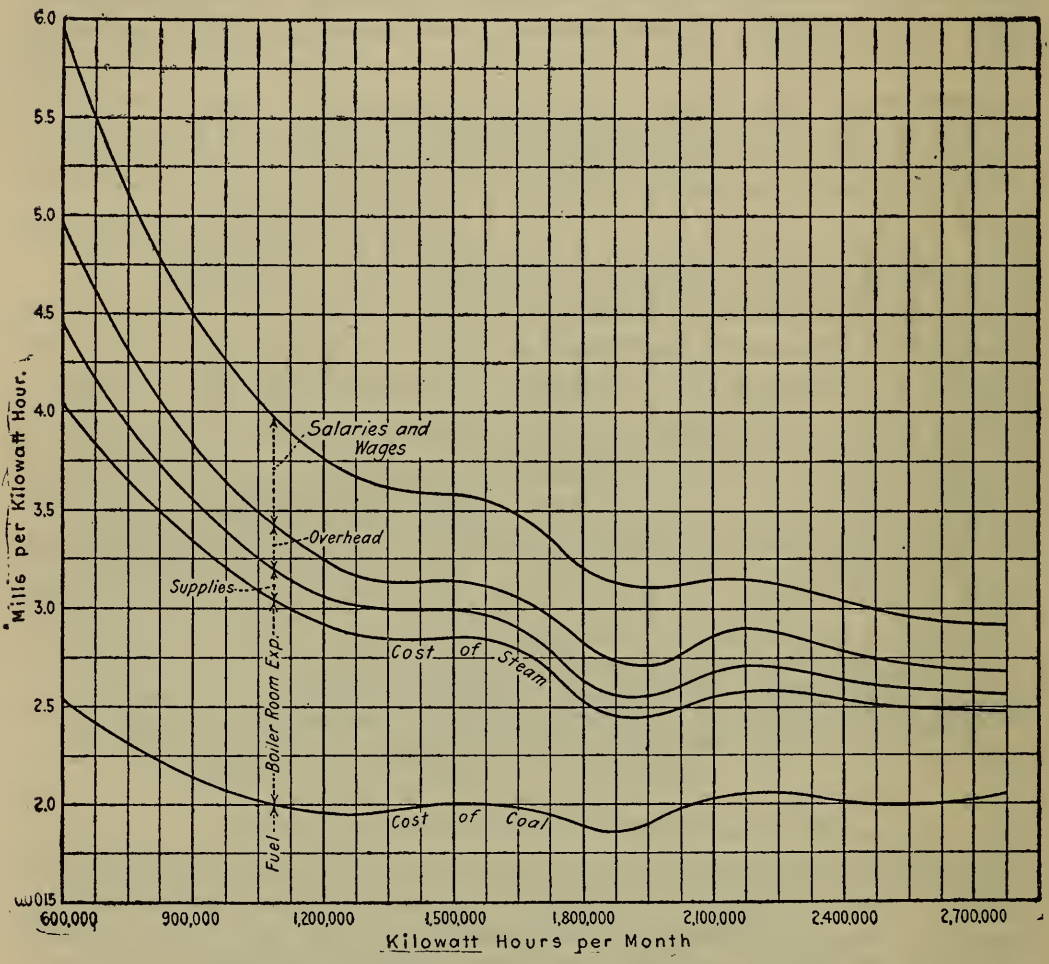


FIG. 113.—CURVES OF STANDARD OPERATING COST

This diagram represents standard expenses of a carbo-electric portion of a plant of a public utility company; hydro-electric plant standard expenses are shown in Fig. 111. Costs based on prices prevailing in 1913.

station feeding the lines of an electrified trunk railroad. The plurality of waves on the fuel-cost curves, etc., is due to the decrease of efficiency occurring every time an additional unit is cut in and until the load on all reaches a more favorable point. The tendency of the total standard cost curve to go steadily downward with the increase of the output rate is due to the water rate of generating units, higher boiler efficiency, reduced banking, etc., as well as to distribution of other expenses over a large output.

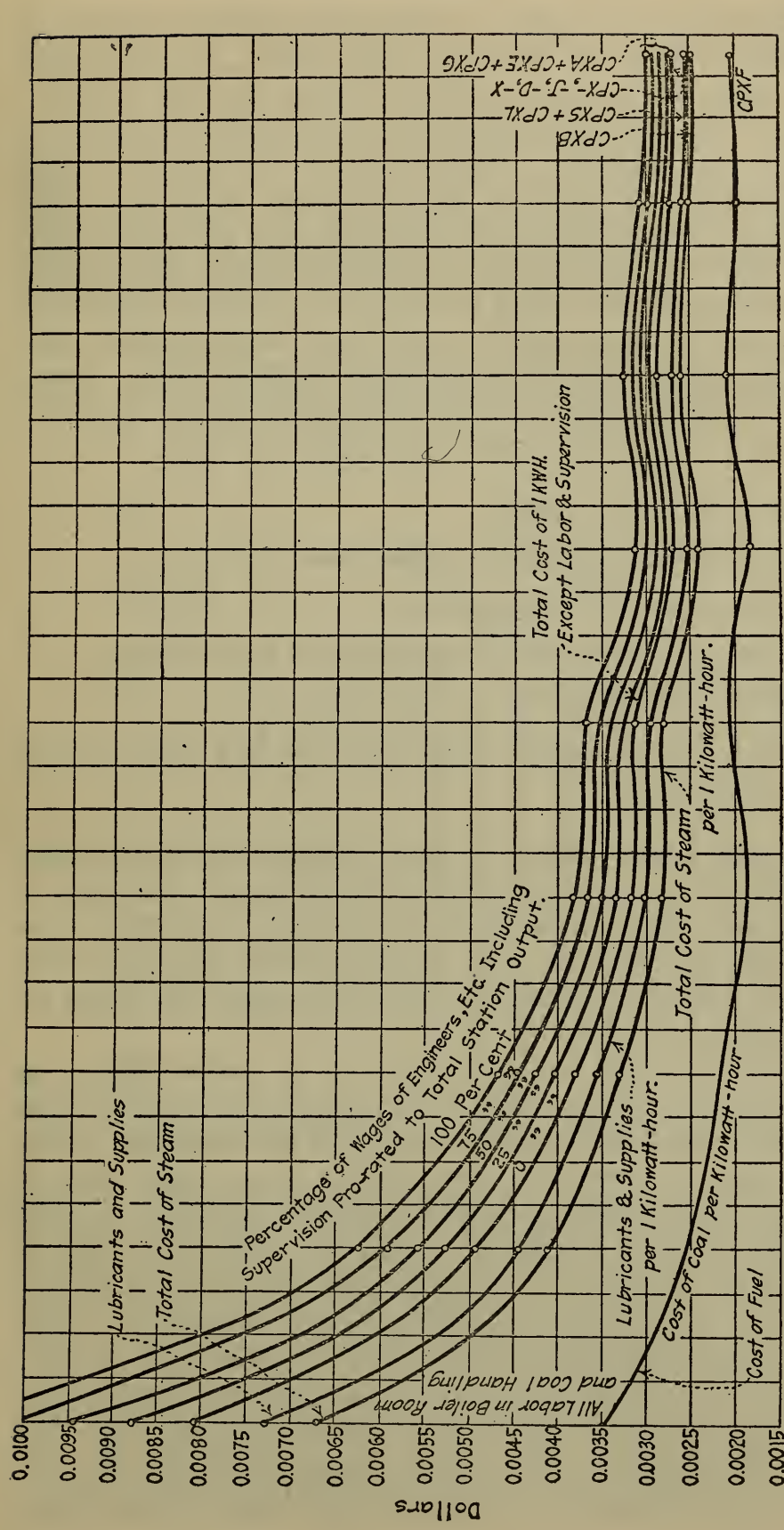


FIG. 113a.—CURVES OF STANDARD OPERATING COST

Prepared for the same plant and under the same operating conditions as Figure 113, based on daily output.

The practical use of such predetermined standard costs can be made extremely simple by employing these graphs. For busy executives or owners, the entire cost record visualized by graphical representations of the items of the account is found very convenient. An example of such a graph is seen in Figure 114, wherein the actual unit cost and the standard unit cost are plotted to the same scale, the deviation of one from the other suggesting at a glance the degree of perfection of the performance. The total-expense curve and the cumulative-expense curve may be shown on the same graph to a suitable scale; the latter curve is found very serviceable for comparing these items with the appropriation made. A cost system kept on a card file in this manner will represent clearly in any desired detail for any period and at any time:

1 How much was spent
2 How much each unit of output cost
3 How much it should have cost
4 What the fluctuations of expenses and unit cost are
5 What the fluctuations of efficiency are
6 How close the actual amount spent in any time is to the appropriation.

The accuracy of such graphic records is sufficient for most practical uses and refernces, as it allows the interpolation of unit costs to 0.01 of a cent. If the exact total of expenditure is wanted, it can be had at any time from the book records, whereas the use of books and figures exclusively lacks the comprehensiveness and visual instructive value of graphs.

Any comparison of the production costs of various plants may now be made in a different light. By comparing the standard costs of one plant with those of another, one gains the knowledge of how much cheaper the power can be produced in one plant than in another, due to its various physical advantages, corrections for load and output all being automatic. Again, by noting how near the actual cost of one plant is to its standard cost, one has at once a measure of the quality of the methods and management. Thus, referring again to Figures 112 and 113 the actual cost per kilowatt-hour of 35 cents in one plant means a worse operating economy than 48 cents in another plant under another load condition. Yet without such accurately predetermined standard costs that are individual for each plant and condition of load, correct comparison is

impossible, and conclusions from a mere study of accountant's figures are apt to be grossly in error.

Figure 111 reproduces a diagram of standard cost for a hydro-electric plant consisting of four 600 kilowatt generators. This equipment is located in a hall adjoining the turbine room of a plant whose standard costs are shown on diagram Figure 113; same crew attends to both steam and hydroelectric equipment; the payroll is prorated between the outputs of each. The cost of

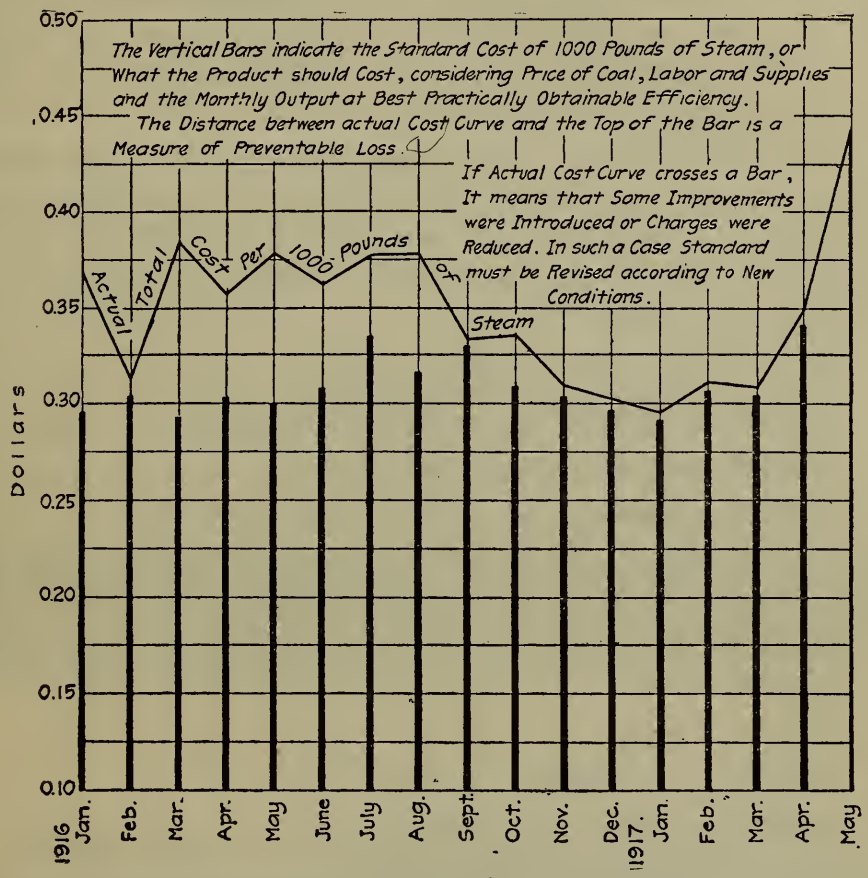

The Vertical Bars indicate the Standard Cost of 1000 Pounds of Steam, or What the Product should Cost, considering Price of Coal, Labor and Supplies and the Monthly Output at Best Practically Obtainable Efficiency.
The Distance between actual Cost Curve and the Top of the Bar is a Measure of Preventable Loss.
If Actual Cost Curve crosses a Bar, It means that Some Improvements were Introduced or Charges were Reduced. In such a Case Standard must be Revised according to New Conditions.
Actual Total Cost per 1000 pounds of Steam
Dollars
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
1916 Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. 1917. Jan. Feb. Mar. Apr. May

FIG. 114.—GRAPHIC COMPARISON OF ACTUAL AND STANDARD UNIT COSTS

power is thus regarded as the result of methods used on one side and given physical conditions on the other. If the cost analysis succeeds in segregating these elements and measures each, the most valuable knowledge will be secured. If the prices of materials, supplies and labor are known, the efficiency and characteristic of equipment used are also known; the nature of service, character of load and some local factors would influence the expenses in a manner not difficult to determine. In a given plant all these elements remain constant until a change is made by a new installation, new market prices or a new field of service, etc., all of which are readily notice-

able and accountable. Now if the costs still fluctuate, the difference between the actual cost and the predetermined is due to the variation of the methods of management of the plant. If these methods are studied, the best way selected, the men trained and the practice standardized, and still the costs deviate from the predetermined standard (other conditions being constant or equated for) it means that the task is not lived up to; that is, the management fails to manage.

This method of studying costs offers therefore a measure of efficiency of the plant management. If the principles and methods selected and used are right, the results will necessarily be as expected and the best known (standard) method finds its expression in the predetermined cost (standard).

A cost system developed along these lines will not only afford a means for clearly understanding the operating and managerial problems, but offer a basis for cost comparisons of different plants. The essentials of the knowledge gained through comparing actual with standard costs are:

1 Relative supremacy of plants proper
2 Relative advantages of managerial methods
3 Relative extent of preventable losses
4 Relative advantages of prices of materials, etc.

These cannot be found unless there is a comparable basis or scale for comparison, which is offered by standard costs determined for each plant individually, as at least ten main variables must be accounted for as follows:

1 Nature of load
2 Character of service
3 Conditions imposed by location
4 Inherent efficiency of equipment
5 Arrangement of equipment, floor plan, etc.
6 Cost efficiency of fuel and supplies
7 Legal requirements
8 Methods of operation
9 Labor conditions
10 Methods of compensation for service.

Each of these variables being in its turn a product of a plurality of factors, it is manifestly impossible to state, without the aid of carefully worked out standard costs, that the economy of one plant or another is satisfactory, or where and how it can be bettered.

Inasmuch as the standard cost cannot be determined without first finding out how the maximum economy can be secured, the process of standardizing costs invites a process of devising the best way for operating and managing. Once both methods and results are positively established, costs are but a form of expressing the final result. It is true that standard cost is influenced by the prices of commodities used in connection with the generation of power, as well as by some conditions beyond the control of the management and the operating engineers, but the adjustment of the standard costs to every change of these factors can be made as simple as the use of a slide rule. Furthermore, a separate account should be kept for such charges as are due to business policy, so that *a division of responsibility between those managing the production and those directing the business could be drawn.*

So long as costs of producing power come as an unexpected surprise and arouse the curiosity to an extent of comparing them with the preceding month, year, or some other plant's data, the management of such power plants is evidently very haphazard, lacking an aim at any definite goal. Without predetermined standards, superintendents and managers will continue to believe that they control the production, and owners will remain in happy ignorance as to how much of their money goes to waste and why. Only after the establishment of standards and ideal costs of production by means of the most rigorous analysis will cost accounting be of help to the engineer, and only then can it be said that the generation of power is directed by the management and controlled by the engineers.

Expenses of Idleness

In the chapter on equipment, reference was made to the effect of time-rate of the use of equipment on the economy. Figures 28 and 29 illustrated the increase of a non-productive portion of fixed charges with a decreased plant output. In the case cited this increase of unabsorbed expenses of ownership of excessive plant was $1,645 per week or about $85,500 per annum. The question we are facing now, in connection with our analysis of plant expenses is twofold: first, how to allocate these expenses, and second, whether these expenses constitute any part of the cost of the product.

In the past the ready answer to both these questions was uniformly that of summary dismissal of both, for the reason that the ultimate consumer was called upon to pay the entire expense of over-equipment. In cases of manufacturing plants these expenses,

as a portion of auxiliary expenses, were prorated over the factory output while in cases of public utility plants a solution of the problem has been sought in attempts to secure "off-peak load" tending to minimize the idleness of equipment. While this course is unquestionably in the right direction, the methods were frequently at fault inasmuch as the failure to properly allocate the exepnse of idleness, pretty generally penalized the small consumers.

The loss caused by over-equipment is primarily a social waste. Materials are consumed to produce machinery that remain inoperative; men spend their time building things which do not serve any useful purpose. Consequently capital representing these useless expenditures does not take any part in the creation of new commodities nor does it play any part in rendering useful service. Nevertheless the investors, ill-advised or ignorant on the point of curtailing the productive capacity of the country, continue to claim the return on their investments. The obvious way to secure this return was to distribute the expenses of ownership of idle equipment over the limited product of working machines. This method increased the cost of the product without increasing the earning power of the population or, in other words, *due to the practice of extracting return on non-productive investments the cost of living increases faster than the wages.*

In a poem published as far back as 1831 in the *Poor Man's Guardian* a few lines bear witness that this economic fallacy was recognized nearly a hundred years ago:

> "But if the price be made of rent,
> Titles, taxes, profits all
> Then we, who work to make the goods,
> Shall have just none at all."

Yet a recognition of an evil does not bring any relief until its extent is accurately measured and means are developed to ameliorate the condition.

A few actual examples may be to the point. The cost of ownership of a mill power house is $3,000 per month and the normal monthly output of steam for power, heating and processes is 15,000,000 pounds. The total production expense per 1000 pounds of steam (part in which is converted into various forms of power) is averaging 40 cents and the total cost per 1000 pounds converted steam is, including the cost of ownership, 60 cents. If figured out per unit of the mill product the cost of power would be, when running full, 5 cents. In fact the plant is twice as large as is needed to meet

the mill's demand and only 7,000,000 pounds of steam (converted) is consumed per month. In this case prorata of ownership cost per 1000 pounds is 40 cents and the total cost of power and steam 80 cents per 1000 pounds and the cost of power per actual unit of mill's output is 6.5 cents.

In this manner the consuming public by buying the product of this mill, which has twice as large a power house as it needs, pays yearly about $18,000.00 for which it receives nothing in return. This example was picked out advisedly from our records as it is typical of a small plant a large number of which constitute our great industry.

While the method of collecting and recording data of this nature was outlined in the preceding chapter, their application to analysis of costs and expenses entails a special procedure. Certain simple records are usually kept in a plant to enable accurate analysis of idle time and proper allocation of causes. Generally an intelligently composed power-log furnishes the necessary basis for the disbursement of the non-productive portion of power expenses. If the expenses are prorated on the hourly output or plant-section basis, the number of hours each unit was in operation, ready for operation or idle should be recorded and preferably graphically. As this method is somewhat complicated, it is warranted only in plants where a great variety of units of widely different types is used. Ordinarily only the following records are needed:

1 Net output: kilowatt hours (or pounds of steam)

2 Hours and number of boilers banked and generators phased for stand-by service

3 Hours and number of water wheels idle (due to lack of water power or lack of load)

Cost of idleness from the above data is summarized on a chart which combines graphical visualization with actual figures and analyzes the cause of idleness into classes. It may be also arranged to show daily fluctuations. By the division of a plant into three general groups: generating steam, generating electricity and transforming and feeding energy into lines, an extra usefulness is added for, besides measuring a loss and allocating at a glance its cause (which knowledge stimulates and helps to find means of a better utilization of equipment), it shows clearly whether any group of equipment is disproportionately large or which process (if any) acts as a damper on a more complete utilization of the rest of the equip-

ment. Such a chart may be blue-printed and distributed among all the officials whose co-operation is capable of wiping out the loss.

To illustrate this procedure let us consider a mill power plant which carries the following fixed charges:

Interest on investment	$4,000
Interest on coal and rent	500
Taxes	1,950
Insurance, fire	75
Insurance, boiler	550
Insurance, liability	125
Insurance, fly wheel	70
Depreciation	9,500
Total per year	$17,770

Since this plant generates both steam for processes and electric power these charges are differentiated as follows:

	Annual	Hourly
On boiler house	$9,665	$1.35
On engine room	8,105	1.12
	$17,770	$2.47

Inasmuch as the safe output of boilers with due reserve is 54,000 pounds per hour the overhead charge per 1,000 pounds is 2.5 cents whereas the charge per kilowatt hour is 0.112+0.09=0.202 cent.

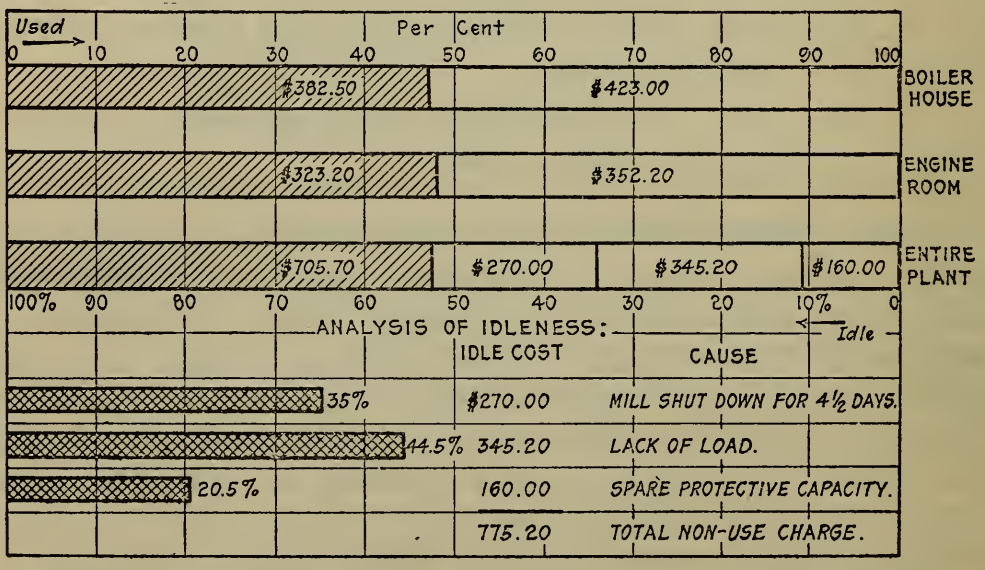


FIG. 115.—EXPENSE OF IDLENESS IN A TYPICAL FACTORY POWER HOUSE

The chart represents the average distribution of idleness and idle costs of a large number of factory and mill power plants, both during and before the war.

If during a month the steam output was 15,300,000 pounds and the electrical output 160,000 kilowatt hours, the charges were prorated as follows:

	Absorbed	Idle	Total
On steam plant (15,300× 2.5)	=$382.50	423.00	805.50
On electric plant (160,000×.202)	=$323.20	352.20	675.40
	$795.70	775.20	1480.90

In other words, more than half of the capacity of the plant was idle during this month. This in itself was analyzed by causes as follows:

Avoidable	Lack of load when running	$345.00
	Mill shut down 4.5 days	$270.00
Unavoidable.	Reserve capacity	$160.00
		$775.20

This rather lengthy story is clearly represented on a chart (see Figure 115) which requires no further explanation.

Another interesting case is shown by the chart Figure 116 representing several months performance of a power plant serv-

WORKING PERIOD 38 WEEKS 5 days — Main Power Plant DEPT.

DEPARTMENT OR MACH. CLASS	% OF CAPACITY USED ON Monthly TURN (10 20 30 40 50 60 70 80 90)	EXPENSE OF IDLENESS: TOTAL $	UNAVOIDABLE %	UNAVOIDABLE AMOUNT	INCREASE IN EXPENSE OF PRODUCT %	AVOIDABLE $	REMARKS on Cause of idleness
April		2213.28			8.2	2213.28	55.3% Due lack of work in Mill
May		2054.86			11.8	2054.86	50.1 "
June		2350.33			10.4	2350.33	58.9 "
July		2264.64			9.8	2264.64	56.6 "
Aug.		2400.66			12.1	2400.66	60.01 "
Sept.		2424.45	35.1	1406.21	12.3	1018.24	60.05 Due lack of repair part and lack of orders 25.4%
Oct.		2423.24			11.6	2423.24	60.05 Due to lack of orders in mill
Nov		2371.36			12.4	2371.36	59.3 "
Dec.		2905.00			13.4	2905.00	72.6 " also due holiday shut down
9 Month of '18		21401.57			11.22	21401.57	

FIG. 116.—POWER HOUSE IDLE EXPENSE REPORT

Factory power plant having capacity in excess of the shop demand for power, causes the increase in cost of power by 11.22% due to excessive ownership expenses.

ing a large manufacturing concern. The value of the plant was taken as follows:

Furniture and fixtures	$612.50
Electric wiring	2,236.32
Machinery	260,272.41
Tools	498.53
Piping	65,750.37
Motors	3,911.86
Power wiring	9,507.27
Shafting and belting	375.46
Foundations machinery	8,219.65
Power machinery	1,307.02
Structures	138,131.19
Tunnels and conduit	21,446.04
Sprinkler system	27.00
Fire lines	2,361.35
Extinguishers	5.25
Reservoirs	18,138.55
Total	$532,800.77

The accounting department fixed a monthly charge on this plant at only $4000 which is extremely low. The total capacity of this plant is 50,000,000 pounds of steam per month. Allowing 20 per cent of this capacity for protection, regular repair, and unavoidable periods of low demand (lunch hour) we can safely secure from this plant a monthly output equivalent to 40,000,000 pounds of steam. The fixed charges thus distributed through the full safe output make a surcharge per 1,000 pounds of steam equal to 10 cents. The actual situation is represented by the chart of Figure 116. It appears that on the average of nine months, 59.4 per cent of the plant capacity remained unproductive and that during the same time for this cause alone the increase in expense of the product (power) due to this cause alone was 11.22 per cent over what it would have been if the factory had the use for the full capacity of the power plant.

This last figure, however, is in reality underestimated, since at that time, with low load and poor operating practice the operating cost per 1,000 pounds of steam converted into diverse forms of power was about 75 cents. The same plant after a new mode of management was inaugurated, generates 1,000 pounds

of steam converted, for 48 cents, the true increase of expenses due idleness was therefore approximately 25 per cent.

A situation, as disclosed above, presents a serious problem for the management and, as in the case cited, where lack of demand for power was principally caused by the factory running light, the matter was presented to the sales manager who, realizing the situation, succeeded in securing enough work not only to absorb the expense of idle equipment, but indeed a year after it became necessary to install in this plant an additional turbo-generator to take care of the increased factory load.

How evidently wrong is the practice of charging the expenses incurred during the idleness of the plant equipment against the product manufactured in a factory not requiring all power equipment is thus gradually realized by manufacturers and by the public at large. Yet the question of whether it is right for the public utility company to charge against its customers the expense of keeping a large portion of its generating equipment idle[128] has not received so far its due attention.

Mr. W. F. Schaller, in his address at the Boston meeting of The American Society of Mechanical Engineers in 1917, referred to this matter in connection with his topic of conservation of power resources by means of coöperation between central stations and private power plants. Said he:

"Any expense which is necessary merely to supply these 300 hours or so of peak load should under any proper system of bookkeeping be charged with the interest, depreciation and other fixed charges arising from the investment necessary to supply this peak is not confined to the generating station, but extends in increasing proportion to the sub-station, the feeder and main system and the service and meter in connection. In other words, if one-half of the total investment in generating plant, transmission system, sub-station, feeders, mains service connections and meters is made necessary in order to supply the peak load lasting 300 hours during a year, the cost of supplying this peak load for these 300 hours is the sum of the operating cost and a due proportion of the overhead charges and one-half of the total fixed charges. These fixed charges would include interest on the total investment, rental of subways, renewal and contingency reserve, probably the larger portion of the taxes would also have to be included under the fixed charges divisible in the way stated. These fixed charges would ordinarily amount to more than the

total operating expenses. In one large company—to give a concrete example—the operating expenses per kilowatt hour delivered to the consumer were 1.96 cents. The fixed charges as enumerated above were approximately 2.5 cents per kilowatt hour. The total of fixed charges was in the neighborhood of $10,000,000 and the operating expenses about $8,000,000. The total number of kilowatt hours delivered to consumers was over 400,000,000. If we call the peak of the load that over 70 per cent of the maximum and we assume that this peak was delivered for 400 hours a year the maximum load being 210,000 kilowatts hours found 25,000,000 kilowatt hours or 1/16 of the total amount delivered to consumers would equitably have to bear 30 per cent of the fixed charges and in the case discussed this would amount to 12 cents per kilowatt hour, which of course would be in addition to the operating expenses. Carrying the discussion further, it will be remembered that one kilowatt of the peak at the station was required for each kilowatt of the large user's demand so that properly speaking the larger user costs the public utility 12 cents per kilowatt hour for the peak load required by him. On the other hand the residence consumer, who only requires one-fourth of a kilowatt for every kilowatt of maximum demand in his residence, costs the public utility company about 3 cents per kilowatt of maximum demand. The commercial consumer at retail quantities would come in somewhere between the two. This is interesting in connection with the claim so frequently advanced that the large consumer is less costly to supply than the small consumer."

While the above quotation is used merely as an example, the conditions mentioned are typical enough to emphasize the fact that in the case of public utility service the expenses accumulating during the idleness of generating and transmissoin equipment require more study than they have heretofore received. Furthermore, it is clear to any unbiased mind that while the character of the service offers some complication to the solution of the problem, the off-peak load or productive use of the otherwise idle equipment, should reduce the burden of idle charges, yet the attractive rates for such services are frequently offered at the expense of another group of consumers, thus substituting an evil of idleness by another evil of taxing the weakest consumers for the service given to others.

Classification of Expenses

In order to meet the fundamental requirements of cost keeping, all expenses incurred must be properly classified. There are three main groups of expenses:

1 Productive expenses

2 Non-productive expenses

3 Expenses of idleness.

Productive expenses are all such expenses as must be necessarily incurred to produce the commodity of desired quality and in desired quantity and thus contribute to the value of the product.

Non-productive expenses to the contrary, are such expenses that either may be eliminated altogether or have no bearing on the quality or value of the commodity actually produced. Excessive fuel consumption may exemplify this group.

Expenses of idleness include such expenses as rent, interest, depreciation, insurance, etc, of the idle portion of the plant, damages due to interruption of service and the like, prorata on the output of administrative business and other expense if the plant is not operated at its safe full capacity and, in case of the complete shut down of the plant, it comprises all the expenses incurred during the period of idleness or caused by it.

In this connection it is important to note that in a manufacturing concern the power plant represents merely an auxiliary department and therefore in all matters of cost keeping and accounting it should be considered as an outside concern independent of the establishment it serves. It should be constantly borne in mind that the service it renders could be bought from outsiders and for this reason the factory power plant should be operated as if it were in competition with power plants belonging to other people. On this basis it should show a profit or loss to the *business*. The charge for its service should be made on the basis that this plant was being operated at its full capacity, that is in case the demand of any of the manufacturing departments is below the allotted capacity, it should be charged with the expense of ideleness of the plant, yet this charge should be shown separately from the service charge proper. By means of such comparisons and consideration of the "unabsorbed burden" of the power plant, it will be possible to

estimate what economy results from operating one's own plant, or what the convenience of having it is costing the concern.

The same reasoning applies in the case of a public utility company having auxiliary departments such as a carpenter shop, a creosoting plant, a machine shop, a laboratory, etc., as it is essential to know what are the advantages of having these as against having these respective services rendered by outside establishments. There is no necessity of describing here in detail all possible methods of classification intelligently adapted to the nature of the work done and based on the principle of such a division as is here discussed and which allocate the useless waste caused either by incompetence or ideleness. By way of reference, mention can be made of two successful attempts to classify the itemized expenses, without however, a clearly drawn division line between productive, useless and idle expenses. The first one was devised in 1912-13 for the Penn Central Light & Power Co. and the second is the standard method of accounting adopted by the National Electric Light Association. Whatever is the practice, the following grouping of expenses helps materially to properly allocate any item.

Administration expenses include supervision, foremanship, business expenses, transportation, general supplies, rearrangements and betterment, damages and liabilities and all overhead or fixed charges.

Auxiliary expenses may be regarded as a subdivision of administrative expenses and are those incurred from outside; such as laboratory, trucking, machine shop, etc. Separation of this kind of expenses is necessary for decision whether or not the continuation of their services is desirable.

Maintenance expenses are those necessary to maintain the plant in perfect operating condition at all times and include all labor, materials and supplies used in the maintenance and repair of the property and equipment, but do not cover expenses of running operating upkeep.

Operating expenses are those incurred for securing all such labor, materials, supplies, etc., which are used in the process of generation and are transformed into power in one form or another.

Each one of these classes should, of course, be further subdivided into such detail and separate items as may be warranted for the purpose of itemized analysis of expenses. Allocation and measurement of waste and derivation of true cost of product and idle or non-productive expenses. As has been shown before,

rent and other fixed charges on the idle portion of the plant are segregated and kept not as a part of cost of product but as *business loss* and their relative magnitude serves as an incentive and guide for the efforts of the new business department in a public utility company, while in a factory power plant such a business loss on excess power capacity may indicate either lack of work in manufacturing departments or else an original over-estimation of power requirements. A remedy may be found by increasing manufacturing while in the second case either by disposing of excessive power equipment or by selling power generated by otherwise idle equipment. The author has had experiences along such lines and the price at which the isolated plants were able to furnish power to outside customers was but a fraction of usual public utility rates.

Obviously administrative expenses shall be treated in the same manner. If an administrative organization maintained at a certain expense is capable of handling the plant producing full output, half of the output should not bear double surcharge as the consumers do not get any additional value from a "kilowatt hour" thus overburdened.

Similarly the expenses of maintenance remain nearly the same whether the plant is loaded to the safe-full capacity or greatly underloaded. The simplest and most logical way of pro-rating these expenses between a productive and non-productive group is by the percentage of the actual output to the pre-determined safe-full output of the plant. A kilowatt hour is thus a convenient unit for an electric plant, while in a factory power plant furnishing a variety of forms of power the basic form-steam measured say by 1,000 pounds or in boiler horse-power renders a fair and convenient basis.

In this manner the classification of expenses is carried at once in two directions—as to item: by classes such as operation, maintenance and administration; as to groups: such as pro-ductive, non-productive and idleness. On an actual form in use by several manufacturing plants reproduced in Figure 117 this double classification is plainly illustrated, class divisions being arranged vertically and group divisions horizontally. We will return to this subject under the heading expense analysis.

A not uncommon purpose to which cost reports are some-times put is that of a comparison of expenses incurred in power production either in the same plant a year or a month ago, or for a comparison of expenses of different plants either competing

TABLE II—COMPARATIVE COST OF OPERATION AND MAINTENANCE OF POWER PLANTS—JUNE, 1915

			A		B		C		D		E		F		G	
			Dollars, Total	Cents per kw-hr.	Dollars, Total	Cents per kw-hr.	Dollars, Total	Cents per kw-hr.	Dollars, Total	Cents per kw-hr.	Dollars, Total	Cents per kw-hr.	Dollars, Total	Cents per kw-hr.	Dollars, Total	Cents per kw-hr.
Operation	Labor	Boiler Room	2233.21	.036	1639.45	.056	2686.34	.025	4967.27	.0195	3076.18	.0318	3283.50	.0855	1133.95	.052
		Turbine Room	1116.52	.018	679.89	.024	1682.89	.016	3156.36	.0124	1471.10	.0153	1472.54	.0383	756.10	.035
		Electrical	1080.52	.018	522.75	.018	536.12	.005	982.22	.0039	1105.73	.0114	264.28	.0120	144.87	.007
		Superv.—Janitors and Watchmen	563.14	.009	531.99	.018	601.26	.006	1230.89	.0049	460.85	.0048	1061.43	.0276	149.80	.007
		Total Operating Labor	4993.39	.081	3374.08	.116	5506.61	.052	10336.74	.0407	6113.86	.0633	6281.75	.1634	2184.72	.101
	Material	Coal	20535.00	.335	7338.55	.252	29945.89	.285	73803.55	.2908	35260.67	.3648	11820.31	.3075	8587.80	.395
		Water	675.65	.011	59.56	.002	1618.32	.015	475.42	.0019	1353.96	.0141	789.18	.0205	30.69	.002
		Lubricants	84.02	.002	61.11	.002	44.88	.001	226.47	.0009	270.81	.0028	135.68	.0035	68.13	.003
		Miscellaneous Material	194.55	.003	157.30	.005	27.70	.000	2043.91	.0080	35.12	.0004	555.73	.0145	149.87	.003
		Miscellaneous Charges	20.91	.000	Cr. 1.55	.000	757.96	.007	....	...	....	...	....	...	129.87	.000
		Total Operating Material	21510.13	.351	7614.97	.261	32394.75	.308	76549.35	.0316	36920.56	.3821	13300.90	.3460	8966.36	.413
		Total Operation	26503.52	.432	10989.05	.377	37901.36	.360	86886.09	.3423	43034.42	.4454	19582.65	.5094	11150.86	.517
Maintenance	Labor	Building	40.95	.001	129.36	.004	190.19	.002	1312.28	.0052	140.91	.0015	77.35	.0020	2.35	.00
		Boilers	291.36	.005	319.27	.011	703.13	.007	641.67	.0025	751.72	.0078	279.49	.0073	139.45	.00
		Boiler Room Auxiliary Apparatus	173.89	.003	268.33	.009	594.54	.005	520.47	.0020	280.40	.0029	66.15	.0017	31.49	.00
		Turbines	1055.16	.017	27.49	.001	328.36	.003	55.50	.0002	361.42	.0037	286.24	.0075	1.84	.00
		Auxiliary Apparatus	142.08	.002	21.23	.001	561.59	.005	322.21	.0013	176.86	.0018	334.92	.0087	6.83	.00
		Electrical Apparatus	9.32	.000	1.50	.000	399.57	.004	119.43	.0005	353.12	.0037	85.69	.0022	1.23	.00
		Piping	85.83	.001	54.03	.002	389.61	.004	433.24	.0017	119.59	.0012	131.69	.0034	136.05	.00
		Miscellaneous	49.40	.001	55.06	.002	132.23	.001	55.69	.0002	396.04	.0041	1.92	.0001	23.78	.00
		Total Maintenance Labor	1847.99	.030	876.27	.030	32.9922	.031	3460.49	.0136	2580.06	0.267	1263.45	.0329	343.02	.01

FIG. 117

		A		B		C		D		E		F		G	
		Dollars, Total	Cents per kw-hr.	Dollars, Total	Cents per kw-hr.	Dollars, Total	Cents per kw-hr.	Dollars, Total	Cents per kw-hr.	Dollars, Total	Cents per kw-hr.	Dollars, Total	Cents per kw-hr.	Dollars, Total	Cents per kw-hr.
Maintenance — Material	Building	212.17	.004	99.98	.004	799.08	.008	3490.00	.0137	2.19	.0000	29.65	.0008	15.14	.00
	Boilers	295.16	.005	66.56	.003	895.22	.008	1389.30	.0055	702.81	.0072	169.67	.0044	457.45	.02
	Boiler Room Auxiliary Apparatus	50.22	.001	40.28	.001	836.39	.008	529.10	.0021	88.08	.0009	73.00	.0019	36.18	.00
	Turbines	78.42	.001	.25	.000	739.08	.007	27.48	.0001	18.35	.0002	78.08	.0020	5.54	.00
	Auxiliary Apparatus	41.08	.001	8.18	.000	1344.22	.013	68.04	.0002	143.86	.0015	1300.79	.0338	28.15	.00
	Electrical Apparatus	14.06	.000	.84	.000	138.89	.001	766.58	.0031	137.70	.0014	162.13	.0042	.....	...
	Piping	20.69	.000	7.94	.000	220.35	.002	574.31	.0023	81.34	.0008	200.10	.0052	149.53	.00
	Miscellaneous	8.76	.000	2.13	.000	127.11	.001	82.47	.0003	209.01	.0022	....	...	60.60	.00
	Total Maintenance Material	720.56	.012	226.16	.008	5100.34	.048	6927.28	.0273	1383.34	.0143	2013.42	.0523	752.59	.03
	Total Maintenance	2568.55	.042	1102.43	.038	8399.56	.079	10387.77	.0409	3963.40	.0410	3276.87	.0852	1095.61	.05
Summary	Total Labor	6841.38	.111	4250.35	.146	8805.83	.084	13797.23	.0543	8693.92	.0900	7545.20	.1963	2527.74	.11
	Total Material	22230.69	.363	7841.13	.269	37495.09	.356	83476.63	.3289	38303.90	.3964	15314.32	.3983	9718.95	.44
	Total Lab. and Mat'l Pow. Sta. Proper	29072.07	.474	12091.48	.415	46300.92	.440	97273.86	.3832	46997.82	.4864	22859.52	.5946	12246.69	.56
	Other Items Chg. to Pow. Sta. Accts.	676.55	.011	676.55	.023	294.42	.003	2024.28	.0080	....	...	966.73	.0252	255.52	.01
	Total	29748.62	.485	12768.03	.438	46595.34	.443	99298.14	.3912	46997.82	.4864	23826.25	.6198	12502.21	.57
	Net Output in kw-hr	6133065	...	2915417	...	10509685	...	25286650	...	9664081	...	3844419	...	2171400	...
	Total Power Generated, kw-hr	6211195	...	2941018	...	10625545	...	25385400	...	9781610	...	4043803	...	2171400	...
	Lb. Coal per kw-hr	2.68	...	2.72	...	2.18	...	2.062	...	2.682	...	3.78015	...	3.40	...
	Cost of Coal per 2000 lb., Dollars	2.50	...	1.85	...	2.613	...	2.803	...	2.72	...	1.61	...	2.33	...
	Load Factor—Machine, Per Cent	59.6	...	74.5	...	64.56	...	73.17	...	86.6	...	49.0	...	64.0	...
	Load Factor—15 Min. Max., Per Cent	45.3	...	23.8	...	36.37	...	90.44	...	58.1	...	35.0	...	112.0	...
	B.t.u. per net kw-hr. Output	38289	...	33513	...	30716	...	29561	...	38046	...	43627	...	49300	...

FIG. 117 (*Continued*)

or coöperating. In the first instance it is sought to visualize the progress made; this is obviously a hopeless task unless the expenses are grouped in the manner permitting direct comparisons of non-productive and idle expenses, corrected for price of materials and labor, etc. Figure 118 represents a cost report carried only as to classes, hence the attempts at superficial comparisons of one month reports with reports of other plants is utterly futile so far as help to the operating force is concerned. In this case we must resort to the use of our standard or ideal predetermined cost (see Figure 111 and 113). In the second instance the efforts spent for comparing cost reports of different plants are even more likely to be fruitless of results, as has been pointed out in this chapter under the heading of predetermination of cost.

One of the functions to which our methods of cost keeping is particularly adapted is to enable the superintendent of plants or chief engineer to know whether or not he is doing the work he is responsible for as economically as possible.

This function is ignored in a majority of cost systems and statistical comparisons are devised so, as to make them admirably successful in making an engineer responsible for blunders committed by the builders of the plant or the shortcomings of the business. Among the greatest sins committed in our industry two are most common and extremely harmful. These are:

1 Lack of supervision

2 Over-equipment.

Late in the autumn of 1914 the author called a conference of operating engineers and superintendents of plants interchanging statistics and cost data. At this meeting, held in the rooms of The American Society of Mechanical Engineers, a plea was made to establish either individual standards for each plant so as to judge how close each management approached its goal or to agree on a definite method of determination of a "factor of merit." A compromise was reached in the agreement that the number of B. t. u. consumed per kilowatt hour would be reported together with the load factor, the price of coal and the output, all uniformly reported on a net basis. This elucidated the subject and enabled them to make a more intelligent comparison of cost data.

In 1913, Mr. H. G. Stott in a paper before the American Institute of Electrical Engineers presented a method for comparing the cost of performance of different plants by simply determining the

THE.....COMPANY POWER PLANT COST ANALYSIS REPORT

MONTH MAY, 1918

Total Coal Used.....1910 Tons

Total Steam Generated.....24,212,299 Lbs.

Average Boiler Efficiency.....51.2 Per Cent

	Labor	Material	Total	Unit Cost	Standard
MAIN POWER HOUSE					
HDO—Total operation	.....	.....	$11,212.76	46.3	36.5
F—Coal	.....	.....	6,717.59	.....	
W—Water	.....	.....	1,534.73	.....	
B—Boiler-room wages	2,083.79	.....	2,083.79	.....	
E—Engine-room wages	443.64	.....	443.64	.....	
L—Lubricants and wastes	.....	.....	4.09	.....	
S—Supplies, miscellaneous	.....	.....	.....	.....	
U—Unclassified expenses	(210.00	218.92	428.92	.....	
X—Credit	.....	.....	.....	.....	
HDA—Total administration	.....	.....	$1,137.14	Per	955.55
A—Foremanship	426.37	.....	426.37	1,000	(year
B—Business expenses	.....	$54.44	54.44	lbs.	average)
E—Experiments	.....	.....	.....	Steam	
C—Fixed charges	.....	.....	319.55	(4.6c.)	
H—Light and power in power house	.....	.....	31.09		
R—Reclamation	.....	.....	.....		
W—Labor	.....	.....	2.89		
S—Supplies	241.28	92.61	241.28		
Y—Yard	.....	.....	.....		
Z—Rearrangement	.....	.....	.....		
X—Credit	.....	.....	.....		
HDM—Total maintenance	.....	.....	$614.82	2.5c.	$500.00
C—Coaling equipment	$30.00	$17.31	47.61		(year
D—Distributing system	15.50	50.00	65.50		average)
B—Boilers and auxiliaries	211.45	112.35	323.80		
G—Generating turbines, auxiliary	6.10	9.09	15.19		
A—Air compressors	64.60	40.08	104.68		
R—Refrigerating equiapment	7.50	.42	7.92		
H—Hydraulic machinery	.....	.....	.....		
P—HP piping	12.40	8.11	20.51		
S—Switchboard and transmission	1.68	.....	1.68		
M—Meters	8.09	2.00	10.09		
T—Tools and implements	.14	14.60	14.74		
F—Furniture and fixtures	.....	.....	.....		
W—Heating and seasoning equipment	.....	.....	.....		
Z—Buildings	3.10	.....	3.10		
X—Credit	.....	.....	.....		
HD—Total Main Power Plant Production	.....	.....	12,964.22	(53.4c.)	
Less Idleness in Main Plant	.....	.....	693.66	50.7c.	42.6
Auxiliary Plant No. 1					
Fuel	.....	93.60	.....		
Boiler-room wages	144.05	.....	.....		
Boiler maintenance and supplies	123.50	40.41	401.56		
Auxiliary Plant No. 2					
Fuel	.....	46.80	.....		
Boiler-room wages	279.06	.....	.....		
Boiler maintenance and supplies	.....	.....	325.86		
Auxiliary Plant No. 3					
Fuel	.....	.....	.....		
Boiler-room wages	290.27	.....	.....		
Boiler maintenance and supplies	.....	.....	290.27		
HD—Total charge to Manufacturing Departments	.....	.....	1,017.69		
Total expense of H. D. Department	.....	.....	13,982.48		

FIG. 118

factors of merit, and, for illustration we shall work the comparative production costs in accordance with this method.

A direct comparison of absolute figures is incorrect and therefore unjust. Power plants, in the first place, have a certain inherent maximum attainable thermal efficiency which cannot be exceeded.

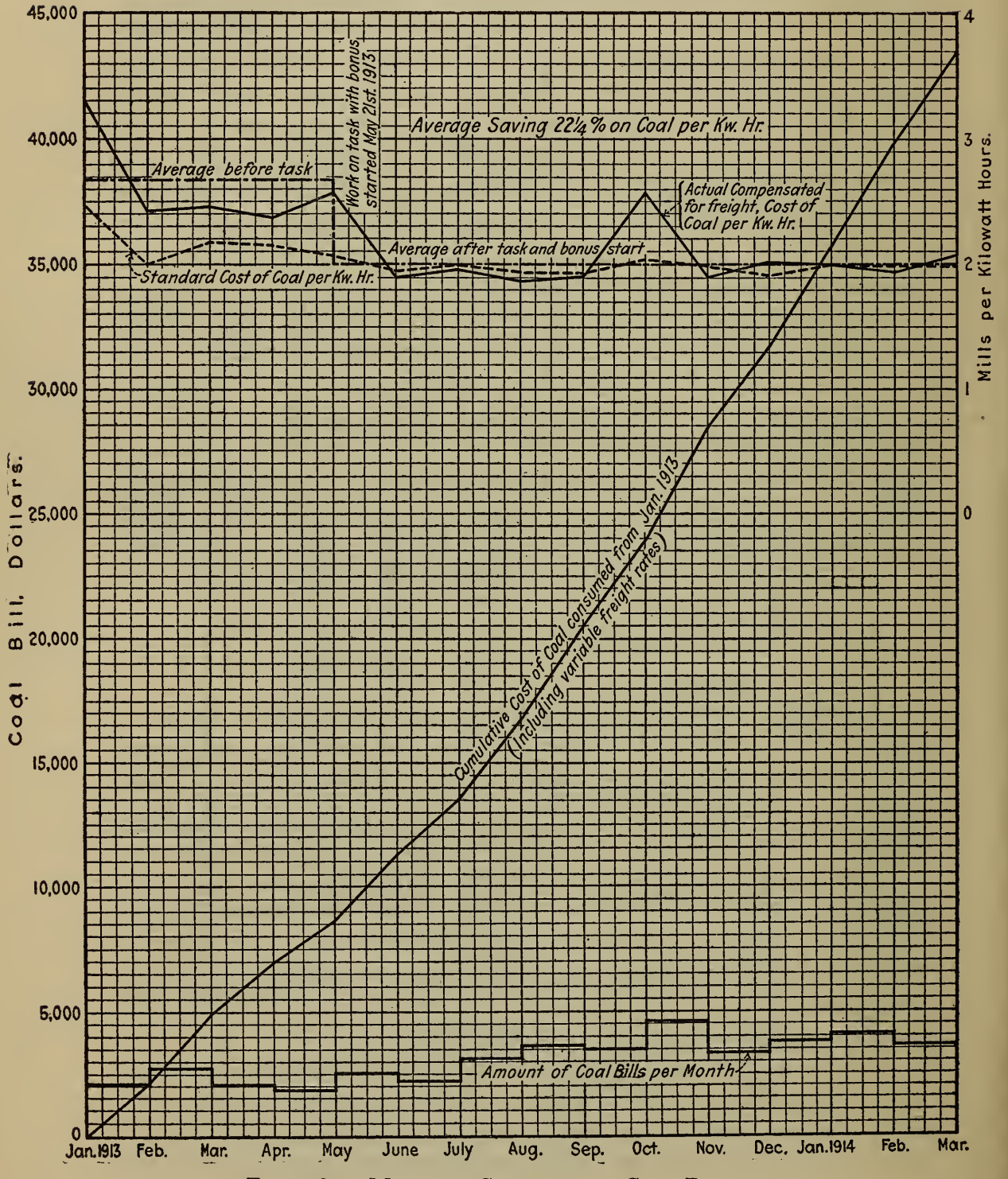


FIG. 118*a*.—MONTHLY COMPARATIVE COST REPORT

They burn coals of various heating values and ash content for which various prices are paid. The nature of their loads is dissimilar as regards load factor and fluctuation characteristics. This brings out the need of some uniform method for determining the cost of power in steam plants whereby the cost in the different plants may be corrected to allow for variations in the load conditions, the cost and quality of fuels, etc.

Probably the two most important factors which affect the costs are the cost of coal and the inherent thermal efficiency of the plant. A rough attempt has been made to standardize the figures given in the comparative statement by the employment of reduction factors for the two items above mentioned. In the following comparison station C is taken as unity.

The simplest method of cost comparison whenever they are not reported on comparable basis, is to establish correction factors for the various plants and then adjust accordingly the total production costs. The average cost of coal for the period covering January, February and March, and the corresponding correction factors are as follows:

Plant	Correction Factor
P—$ 2.50	1.088
Y— 2.054	1.325
L— 2.61	1.042
C— 2.72	1.000
J— 1.61	1.689

The method of procedure is to correct the unit cost of fuel, take the difference between this value and the actual fuel cost and add this difference to or substract it from the total unit cost of production. Applying this correction we arrive at the following figures, with plant C as unity:

Plant	January		February		March	
	Actual	Corrected	Actual	Corrected	Actual	Corrected
P	0.495	0.526	0.553	0.583	0.468	0.496
Y	0.469	0.560	0.487	0.581	0.474	0.567
L	0.440	0.453	0.436	0.449	0.418	0.430
C	0.5066	0.5066	0.5355	0.5345	0.5248	0.5249
J	0.561	0.742	0.528	0.696	0.564	0.744

Using Mr. H. G. Stott's method for determining this factor we have:

$$\text{Figure of Merit} = \frac{\text{B.t.u. per ton (moist)} - \frac{2000 \times \text{per cent}}{100} \text{ cash} \times \text{B.t.u. per lb. of refuse}}{\text{Price per ton}}$$

To correct this for the cost of coal, a reduction factor is necessary which is:

$$\frac{\text{Figure of Merit, Plant } X, \text{ in our case}}{\text{Figure of Merit, Plant } C}$$

Then apply this reduction factor as was done in the preceding paragraph. A uniform ash percetage of 8 per cent was assumed for all stations for the want of more exact data. The figures are as follows, as an average for January, February and March:

Plant	Cost, Dollars	B.t.u.	Figure of Merit	Factor
P	2.50	14,050	11,000,000	1.088
Y	2.054	12,000	11,380,000	1.124
L	2.61	13,980	10,470,000	1.033
C	2.72	14,060	10,110,000	1.000
J	1.61	11,690	14,110,000	1.395

The corrected production costs follow:

Plant	January		February		March	
	Actual	Corrected	Actual	Corrected	Actual	Corrected
P	0.495	0.526 (4)	0.553	0.583 (4)	0.468	0.522 (1)
Y	0.469	0.504 (2)	0.483	0.523 (2)	0.474	0.588 (4)
L	0.440	0.450 (1)	0.436	0.446 (1)	0.418	0.532 (3)
C	0.5066	0.5066 (3)	0.5355	0.5355 (3)	0.5248	0.5248 (2)
J	0.561	0.669 (5)	0.528	0.625 (5)	0.564	0.720 (5)

A factor of merit to compensate for inherent thermal efficiency variations may be determined as follows: From the figures given on the report as B. t. u. per net kilowatt-hour output the tabulated average thermal efficiencies for January,

February, and March are found with corresponding factors of merit plant C as unity:

Plant	Thermal Efficiency	Factor of Merit
P	9.1	1.052
Y	10.0	1.156
L	10.7	1.242
C	8.64	1.000
J	9.2	1.063

Application of this factor to the production costs corrected for coal is shown in the following tables

COAL CORRECTION

Plant	January			February			March		
	Actual	Coal Correction	Efficiency Correction	Actual	Coal Correction	Efficiency Correction	Actual	Coal Correction	Efficiency Correction
P	0.495	0.526	0.554 (2)	0.553	0.583	0.614 (3)	0.468	0.496	0.522 (1)
Y	0.469	0.560	0.642 (3)	0.487	0.581	0.672 (4)	0.474	0.567	0.655 (4)
L	0.440	0.453	0.563 (4)	0.436	0.449	0.558 (2)	0.418	0.430	0.534 (3)
C	0.5066	0.5066	0.5066 (1)	0.5355	0.5355	0.5355 (1)	0.5248	0.5248	0.5248 (2)
J	0.561	0.742	0.789 (5)	0.528	0.696	0.740 (5)	0.564	0.744	0.792 (5)

STOTT'S COAL CORRECTION

Plant	January			February			March		
	Actual	Coal Correction	Efficiency Correction	Actual	Coal Correction	Efficiency Correction	Actual	Coal Correction	Efficiency Correction
P	0.495	0.526	0.554 (3)	0.553	0.583	0.514 (2)	0.468	0.486	0.522 (2)
Y	0.469	0.504	0.582 (4)	0.487	0.523	0.605 (4)	0.474	0.509	0.588 (4)
L	0.440	0.450	0.559 (2)	0.436	0.446	0.504 (1)	0.418	0.428	0.432 (1)
C	0.506	0.506	0.506 (1)	0.535	0.535	0.535 (3)	0.524	0.524	0.524 (3)
J	0.561	0.669	0.712 (5)	0.528	0.625	0.665 (5)	0.564	0.667	0.720 (5)

From the above it is seen that in every case the correction for the cost of coal advances plant C one or more places while the final correction for thermal efficiency moves plant C to the point of *lowest* operating cost, except in March, when it takes second place. Less favorable effect observed when Stott's method of coal correction is used. It will be noted that unit cost for the first six months of 1914 was in plant C 0.685 per kilowatt hour, whereas an average for 1915 is 0.5223 per kilowatt hour. This indicates a cost reduction of 23.7 per cent per kilowatt hour or on the basis of the average output the gross saving accomplished amounts to upward of $175,000,000 per annum.

Analysis of Expenses

For the sake of a brief review of the use of this compiled cost data a few monthly cost summaries are here reproduced taken from different power plants. The table Figure 118 shows a report of a factory power plant running at a low boiler efficiency (51.2 per cent) and greatly underloaded since over 60 per cent of the power capacity is idle. Another peculiarity is too low a payroll due to a shortage of men employed, as well as too low a rate at which no good men can be had. Comparing the actual cost with the predetermined standard, the managerial efficiency is about 90 per cent, while the efficiency of the operating end is only 87.3 per cent. The thermal efficiency of the boilers was 51.2 per cent yet the commercial economy is 71.5 per cent since the standard thermal efficiency of that boiler plant was determined at 71.5 per cent as best possible long average performance.

From this analysis the problem before the management appears in a concrete form. To save $20,000 per year, additional men must be employed and all should be better paid; with thus improved relations a better method of firing and care of boilers should be devised reducing materially the coal consumption and at the same time the maintenance expense which is temporarily high due to a run down condition of the plant which will gradually be lowered as periodic inspection and scheduled overhauling is inaugurated.

A parallel analysis of the table in Figure 120 and Figure 121 is of interest as they fairly illustrate the progress of a plant within seven months of operation after the company had inaugurated our methods. Meanwhile the factory secured more work as indicated by an increased load on the plant and increased pro

MONTHLY EXPENSE STATEMENT

.....Power Plant — For Month of July, 1915

OXX	Operation	Labor	Material	Total	Unit Cost
OXXB	Boiler-room wages	$2,606.45	.....	$2,606.45	.02488
F	Fuel	577.80	$38,708.43	39,286.23	.37508
W	Water	.....	1,235.94	1,235.94	.01179
S	Boiler-room supplies	.....	112.81	112.81	.00108
G	Engineer's wages	1,434.70	.....	1,434.70	.01370
E	Electrical wages	1,203.68	.....	1,203.68	.01150
L	Lubricants and waste	67.45	311.67	379.12	.00362
M	Miscellaneous supplies and expenses	.....	2.38	24.38	.00022
A	Superintendence and administration	290.96	.....	290.96	.00278
O	Records, timekeeper's office	132.68	** 2.60	130.08	.00124
X	Prod. overhead pro rata	.....	.....	.....	.....
U	Unclassified expenses	.....	.....	.....	.....
I	Insurance	.....	.....	.....	.....
	Damages, liability, injury	.....	.....	.....	.....
OXX	**Total for month**	$6,313.72	$40,390.63	$46,704.35	.44589
	Six months' average	$6,165.37	$36,745.48	$42,910.85	.45106

MXX	Maintenance	Labor	Material	Total	Unit Cost
MXXB	Land	$116.95	.....	$116.95	.00111
C	Buildings	34.00	.13	34.13	.00033
D	Dams, canals, etc	*69.55	.....	69.55	.00066
E	Boilers and auxiliaries	892.85	421.77	1,314.62	.01257
F	Gas production equipment	.....	.....	.....	.....
G	Water wheels, etc	.....	.....	.....	.....
H	Engines, turbines, auxiliaries	494.65	*360.29	854.94	.00816
J	Sta. wir. and trans. equipment	12.82	10.25	23.07	.00022
K	Generators and exciters	194.05	24.81	173.86	.00166
L	Switchboard	11.05	13.25	24.30	.00022
M	Transformers in station	25.60	.....	25.60	.00023
N	Station meters	22.80	104.56	127.36	.00121
P	Coal storage and hand	114.80	134.52	249.32	.00239
Q	Station piping	140.80	55.03	195.83	.00187
R	Sid's, trestles and piers	.....	.....	.....	.....
S	Tools and implements	77.85	95.32	173.17	.00166
T	Furniture and fixtures in station	58.40	173.35	231.75	.00221
U	Board and fares, maintenance men	.....	.....	.....	.....
V	Unemployed time, maintenance men	.....	.....	.....	.....
W	Unclassified upkeep	3.87	33.85	37.72	.00036
X	Maintenance overhead charges	280.89	.....	280.89	.00268
MXX	**Total for month**	$2,505.93	$1,427.13	$3,933.06	.03756
	Six months' average	$2,546.39	$1,824.02	$4,370.41	.04593

PXX	Production	Labor	Material	Total	Unit Cost
PXX	**Total for month**	$8,819.65	$41,817.76	$50,637.41	0.48345
	Six months' average	$8,711.76	$38,569.50	$47,281.26	.49699

Output	K.W.H.	B.H.P.
Total generated during month	10,471,360	
Total purchased during month	000	
Grand total	10,474,360	
Lbs. coal per K.W.H.	2,716	
Load factor	86.2% Mach.	49.9% Peak

Clerk	Plan Engineer	Chief Engineer	Accountant	File
G. S.	W.F.S.	Ch. P.	—	8–5–15

Fig. 119

Month, December, 1918. Total Coal Used.....1,965.32 Tons

POWER PLANT " Steam Generated.....21,658,527 lbs.

COST ANALYSIS REPORT Average Boiler Efficiency.....45.7%

	Labor	Material	Total	Unit Cost
HDA—Total administration	.....	.....	$2,316.96	$10.65
A—Foremanship	.....	.....	728.97	
B—Business expenses	.....	.....	81.72	
E—Experiments	.....	.....	.67	
C—Fixed charges	.....	.....	488.49	
H—Light & Power HD	.....	.....	.....	
R—Reclamation	.....	.....	.....	
W—Labor	.....	.....	545.15	
S—Supplies	.....	.....	78.03	
Y—Yard	.....	.....	444.02	
Z—Rearrangement	.....	.....	21.67	
X—Credit	.....	.....	**81.76**	
HDM—Total maintenance	.....	.....	4,183.18	19.28
C—Coaling equipment	.....	.....	53.41	
D—Distribution	.....	.....	46.27	
B—Boilers & aux	.....	.....	2,270.73	
G—Gen., turbines, aux	.....	.....	2,738.22	
A—Air compressors	.....	.....	14.50	
R—Refrigeration equip	.....	.....	13.53	
H—Hydraulic machinery	.....	.....	131.17	
P—HD piping	.....	.....	9.00	
S—Switchboard transm	.....	.....	2.95	
M—Meters	.....	.....	7.16	
T—Tools & implements	.....	.....	260.20	
F—Furniture & fixtures	.....	.....	28.48	
W—Heat & season equip	.....	.....	45.28	
Z—Buildings	.....	.....	27.73	
X—Credit	.....	.....	**1,465.45**	
HDO—Total operation	.....	.....	$17,669.42	$81.40
F—Coal HD	.....	.....	17,264.94	
W—Water	.....	.....	.....	
B—Boiler-room wages	.....	.....	1,837.89	
E—Engine-room wages	.....	.....	819.31	
L—Lubricants & wastes	.....	.....	62.68	
S—Supplies miscellaneous	.....	.....	.....	
U—Unclassified expense	.....	.....	.....	
X—Credit	.....	.....	**2,315.40**	
HD—Total Main Power Plant Production	.....	.....	24,169.56	111.33
Idleness in Main Plant	.....	.....	1,056.53	
	.....	$1,266.40	1,266.40	
Auxiliary Plant No. 1	314.54	.....	314.54	
	.....	.....	273.29	
	.....	.....	227.41	
Auxiliary Plant No. 2	.....	.....	283.56	
	.....	.....	41.26	
	.....	.....	243.91	
Auxiliary Plant No. 3	.....	.....	305.96	
	.....	.....	21.56	
HD—Total charge to Manufacturing Departments	.....	.....	$2,977.89	
Total expense of H. D. Department	.....	.....	27,147.45	

FIG. 120

Month, July, 1919.
POWER PLANT
COST ANALYSIS REPORT

Total Coal Used.....1,774.44 Tons
" Steam Generated.....36,127,500 lbs.
Average Boiler Efficiency.....72.0%

	Labor	Material	Total	Unit Cost
HDA—Total administration	$927.07	$640.50	$1,567.57	$4.30
A—Foremanship	440.35	.....	440.35	
B—Business expenses	.....	120.00	120.00	
E—Experiments	.....	.....	.....	
C—Fixed charges	.....	385.27	385.27	
H—Light & Power HD	.....	.....	.....	
R—Reclamation	.....	.....	.....	
W—Labor	133.41	.....	133.41	
S—Supplies	.....	23.47	23.47	
Y—Yard	325.91	158.70	484.61	
Z—Rearrangement	27.40	.....	27.40	
X—Credit	.....	.....	.....	
HDM—Total maintenance	534.17	2,848.91	3,383.09	9.35
C—Coaling equipment	.....	44.15	44.15	
D—Distribution	.....	.....	.....	
B—Boilers & aux	534.17	691.32	1,225.49	
G—Gen. turbines, aux	.....	1,321.69	1,321.69	
A—Air compressors	.....	41.95	41.95	
R—Refrigerating equip	.....	163.82	163.82	
H—Hydraulic machinery	.....	35.27	35.27	
P—HD piping	.....	8.76	8.76	
S—Switchboard transm	.....	3.33	3.33	
M—Meters	.....	14.32	14.32	
T—Tools & implements	.....	29.51	29.51	
F—Furniture & fixtures	.....	204.30	204.30	
W—Heat & season equip	.....	36.60	36.60	
Z—Buildings	.....	253.89	253.89	
X—Credit	.....	.....	.....	
HDO—Total operation	2,198.46	9,838.14	12,036.60	33.20
F—Coal HD	.....	9,138.37	9,138.37	25.3
W—Water	.....	470.40	470.40	
B—Boiler-room wages	1,451.93	.....	1,451.93	
E—Engine-room wages	746.53	.....	746.53	
L—Lubricants & wastes	.....	174.95	174.95	
S—Supplies miscellaneous	.....	54.42	54.42	
U—Unclassified expense	.....	.....	.....	
X—Credit	.....	.....	.....	
HD—Total Main Power Plant Productoin	3,659.70	13,327.55	16,987.25	46.80
Idleness in Main Plant	.....	.....	.....	
	.....	585.56	.....	
Auxiliary Plant No. 1	334.80	.....	1,150.12	
	.....	229.76	.....	
	.....	148.16	.....	
Auxiliary Plant No. 2	282.72	.....	442.32	
	.....	11.44	.....	
	.....	81.96	.....	
Auxiliary Plant No. 3	230.23	.....	312.19	
	.....	.....	.....	
HD—Total charge to Manufacturing Departments	847.75	1,056.88	1,904.63	
Total expense to H. D. Department	4,507.45	14,384.43	18,891.88	

FIG. 121

rata of business expenses. The average boiler efficiency was improved from 45.7 per cent to 72.0 per cent and consequently 14,468,973 more pounds of steam were evaporated with a coal consumption reduced by 190.88 tons. The total expense was decreased by $7,182.31 the fact of particular interest being that the saving on the coal bill was $8,126.57 although about 60 per cent more power was generated, which of course was made possible by selecting a different grade of coal mixture with anthracite culm, use of forced draft, etc., affecting the price of coal per ton which was reduced from about $8.90 to $5.15.

Referring now to the table of Figure 119, which is the monthly expense statement of a railway plant, it may be fitting to state that this report was accompanied with the following note: "The cost of production at the power plant for July, the first month of operation in the second year under the new mode of management, was 0.48345 cent per kilowatt hour. For the month of July one year ago the cost was 0.558 cent per kilowatt hour. The saving of 14 per cent or about $85,000 on annual basis was accomplished without physical improvement of any kind." In other words the managerial efficiency was improved within a year from 63.5 per cent to 89 per cent while the operating cost efficiency for the month illustrated was 90 per cent compared with the standard cost.

The cost record table shown in Figures 123 and 124 can be studied in connection with the standard cost curves reproduced in Figures 113 and 111. In this connection it might be of interest to note that the attainment of such high efficiency by the plants of this public utility company permitted a revision of their rates and resulted in a very material reduction to the consumers with correspondingly increased net revenue of the company.

The table of Figure 122 is of interest inasmuch as this cost report compiled for a small industrial plant takes full cognizance of the importance of accurate accounting of idle and non-productive expenses.

For the convenience of analyzing expense data they should always be accompanied by explanatory notes giving account of the reasons for the principal fluctuations in cost such as changes in prices, necessity of special work, changes in load conditions, etc., which otherwise would remain obscure in a purely financial statement. An example of such a report prepared in the Superintendent's office of an electrified railroad follows:

"Studying the monthly expense statement for December, 1914, and accompanying cumulative records of plant performance, it might be of interest to note the following points:

"*Fuel.* Total amount of coal consumed was checked by larry scales against the bills of lading. The bill of lading weight shows 26,837,520 pounds whereas the larry record showed 26,738,134 pounds, this being within three-fourths of one percent

POWER COST ANALYSIS — PERIOD X — ENDED OCT, 14, 1919.

Symbol	Class of Expense	Total Expense	Non-Productive Expense	Productive Expense	Unit Cost per M. Lbs. Steam	Non-Productive Ratio
AHA	Total administrative expense..	$863.34	$491.24	$372.10	.066470	56.9%
E	Indirect expense.....	827.32	470.75	356.57	.063696	
B	Experiments and rearrengements.....	36.02	20.49	15.53	.002774	
X	Credits.....	.....	.....	.....	.....	
AHM	Total maintenance.....	$332.48	—	$332.48	.059393	
W	Maintenance, labor and burden	147.37	—	147.37	.026325	
S	Maintenance material.....	197.11	—	197.11	.035121	
X	Credits.....	12.00	—	12.00	.002143	
AHG	Total operating expense	$3,070.46	$69.44	$3,001.02	.536087	
F	Fuel.....	1,928.84	69.44	1,859.40	.332154	3.6%
B	Boiler-house labor.....	589.31	—	589.31	.105273	
E	Engine-room labor.....	272.00	—	272.00	.048588	
L	Supplies and lubricants.....	181.59	—	181.59	.032438	
W	Water.....	98.72	—	98.72	.017634	
X	Credits.....	.....	.....	.....	.....	
	Total per 5,598 M. lbs. steam	$4,266.28	$560.68	$3,705.60	.661950	
	Purchased power.....Kwh. Purchased light.....Kwh.	526.54	—	526.54	.....	
	Total AH expense.....	$4,792.82	$560.68	$4,232.14		

NOTES

Steam generated, total.....	5,598,120 lbs.	
Coal consumed, total.....	580,729 lbs.	
Price of coal per 2,240 lbs.....	$7.18	
Heat value of coal per lb. as rec'd, B.t.u. wet.....	13,585	
Steam per lb. of coal.....	9.64 lbs.	
Efficiency of evaporation (factor 1.06).	72.99%	
Coal per lb. of product.....	2.04 lbs.	284,558 lbs. product
Steam per lb. of product.....	19.67 lbs.	

	Made Out	Engineer	Check	O. K.
Initials.....	E. M. P.			
Date.....	11/1/1919			

FIG. 122

accurate. The shortage of coal weight can be ascribed to a certain extent to the drying out of the coal after crushing and handling same in the boiler room bunkers. There is always,

DETAILS OF OPERATING EXPENSES
ELECTRIC

CP CPW	Production Water Plant	November, 1913		3 Months Ended Nov. 30, 1913	
		Amount	Per K.W.H.	Amount	Per K.W.H.
	Operation				
CPWA	Superintendence	$88.71		$186.18	
CPWD	Damages, injury and liability insurance	20.28		38.69	
CPWE	Engine-room wages	97.19		209.83	
CPWF	Fuel	.29		.29	
CPWG	Electrical wages	68.96		165.77	
CPWJ	Insurance other than liability	.87		1.88	
CPWL	Lubricants	5.16		11.47	
CPWS	Station supplies and expenses	87.61		222.01	
CPWX	Unclassified production expenses	13.45		41.99	
CPW	Production overhead	15.42		60.27	
	Total	$397.94	.0004	$937.38	.0005
	Maintenance				
CPWM–B	Land	$11.14		$2.95	
CPWM–C	Buildings and their equipment	11.14		39.56	
CPWM–D	Dams, canals, tail races	.16		3.56	
CPWM–E	Boilers and auxiliaries	3.24		3.24	
CPWM–G	Water wheels, gates and gov.	13.56		*50.34	
CPWM–H	Engines, turbines and auxiliaries	.27		.98	
CPWM–J	Condensers	4.16		9.55	
CPWM–K	Generators and exciters	3.48		3.52	
CPWM–L	Switchboards	1.04		9.17	
CPWM–M	Transmission in power station	122.96		124.50	
CPWM–N	Station meters	.78		5.54	
COPWM-P	Coal storage and freight equipment	....		.09	
CPWM–S	Machine tools and implements	....		.08	
CPWM–T	Furniture and fixtures in power station	....		1.88	
CPWM	Production overhead	10.22		24.04	
CPWM–U	Board, carfare, maintenance gang	.87		.87	
CPWM–V	Unemployed labor, maintenance gang.	....		11.11	
	Total	$171.88	.0002	$190.30	.0001
	Total production	$569.82	.0006	$1,127.68	.0006
CPWS	Station supplies and expenses	87.61		222.01	
CPWX	Unclassified production expenses	13.45		41.99	
CPW	Production overhead	15.42		60.27	

Daily Average Output.....29,926 K.W. Hrs.
Labor.....35 Per Cent
Standard Unit Cost.....000345
Cost Efficiency.....86.3 Per Cent
Output by Water Wheels, November.....897,770 K.W. Hrs., 35 Per Cent

FIG. 123

of course, the possibility that the car weights are only approximate, weighing of coal being made in Pennsylvania in cars moving over a platform scale at a fairly rapid rate.

"Referring to the weight of coal as shown by the bill of lading to the output of the station, we see that the coal consumption

rate was during December 2.765 pounds per kilowatt hour, whereas in November it was 2.78 pounds.

"Operating Labor. The item of operating labor in the month of

DETAILS OF OPERATING EXPENSES
ELECTRIC

CP CPX	Production Steam Plant	November, 1913			Three Months Ended Nov. 30, 1913	
		Amount	Per K.W.H.	Amount	Amount	Per K.W.H.
	Operation		De-crease −or in-crease + of average of 3 months			
CPXA	Superintendence	$177.47	+ 15		$486.00	
CPXB	Boiler-room wages	1,127.70	− 22		3,447.80	
CPXD	Damages, injury & lia. ins	106.08	− 1		320.55	
CPXE	Engine-room wages	179.66	− 8		562.44	
CPXF	Fuel	3,395.44	−484		11,638.80	
CPXG	Electrical wages	120.49	− 31		453.50	
CPXJ	Insurance other than liability	5.58	− 0.3		17.28	
CPXL	Lubricants	94.85	+ 52		125.25	
CPXS	Station supplies and expenses	182.03	+ 11	Total	512.65	
CPXX	Unclassified pro. expenses	23.51	− 4	decrease	80.03	
CPX	Production overhead	118.03	+ 3	−469.3	345.11	
	Total	$5,530.84	.0035		$17,989.41	.0037
	Maintenance					
CPXM-B	Land	.....			2.07	
CPXM-C	Buildings and their equipment	21.72			115.96	
CPXM-D	Dams, canals and tail races	.28			.28	
CPXM-E	Boilers and auxiliaries	98.09			398.68	
CPXM-F	Produced gas equipment	.....			.06	
CPXM-G	Water wheels, gates, gov	.....			.99	
CPXM-H	Engines, turbines and aux	94.95			355.53	
CPXM-J	Condensers	7.27			21.38	
CPXM-K	Generators and exciters	1.60			2.26	
CPXM-L	Switchboards	1.82			60.66	
CPXM-M	Transformers in power station	216.83			220.14	
CPXM-N	Station meters	1.36			29.17	
CPXM-P	Coal storage, wgt. and equip	.92			4.26	
CPXM-R	Ry. siding and coal trestle	11.90			12.50	
CPXM-S	Machine tools and implements	11.27			13.42	
CPXM-T	Fur. and fix. in power station	1.00			16.18	
CPXM	Production overhead	28.53			55.74	
CPXM-U	Board, carfare, maint. gang	1.53			1.53	
CPXM-V	Unemployed labor, main. gang	.....	+ 3		23.61	
CPMX-V	Unclassified production equip	.....			2.24	
	Total	$498.97	.0003		$1,336.66	.0003
	Total Production	$6,029.81	.0038	−$412	$19,326.07	.004
Per Cent Operation to Total Expenses		.....	91.7			93.1
Per Cent Maintenance to Total Expenses		.....	8.3			6.9

Steam Generated Output for November.....1,569,830 K.W. Hrs.
Labor Percentage.....65 Per Cent
Daily Average Output.....52,328 K.W. Hrs.
Standard Unit Cost.....33.7
Managerial Cost Efficiency.....96 Per Cent

FIG. 124

December was also reduced as compared with the previous month being $6,252.61 as against $6,665.29 in November. This saving has been made possible through a reduction of a number of men operating the traveling coal larries: it being found after time study that one man could attend on the day shifts to both old and new boiler rooms. However, these men were for a while retained as repair helpers during the progress of certain maintenance work going on at the plant, and their resignation was not accepted until they had found new employment.

"*Total Labor.* This however, did not increase the total payroll in December, the cost of labor for both operation and maintenance being $8,674.07 in December as against $9,057.38 in November.

"*Material.* A slight saving has been accomplished also on the item of materials used at the plant in spite of the increased output, the total material used in December being $1,318.70 as against November $1,598.64 which is due to the use of more expensive supplies which last longer and prove cheaper in the end. The items of fuel and water, however, are not included in this total; they naturally vary with the volume of the output.

"*Maintenance.* Going over the items of maintenance we note a slight increase in the cost of maintenance in the repair of boilers and auxiliaries, which is a little over $200 in December higher than in November; this being due chiefly to the lack of proper fire brick for the regular maintenance of furnaces. Item, which was in December somewhat higher than in November, is the coal storage and handling of fuel. Several improvements, repairs and the replacement of parts on the coal tower and trestle were necessary on account of natural wear, as well as winter condition. On all other items of maintenance we report a reduction in costs so that in spite of this extra work done on the above mentioned items the total labor and material for maintenance was $36,029.35 in December as against $36,-049.92 in November.

"*Unit Cost.* From the above cost analysis it is natural to anticipate a certain reduction in cost per kilowatt hour. This has been actually accomplished on every item of classification. Thus total labor and material per kilowatt hour for operation in November was 0.47237, in December was 0.46369. Maintenance labor and material in November was 0.04095, in December it was 0.03643. Total production per kilowatt hour in November was 0.51422, in December 0.49912. In other words,

with the present rate of operation the kilowatt hour is generated for less than one-half a cent as against 0.723 which was an average prior to our regime a year ago.

"*Annual Costs.* A special report will be prepared on the matter of cost of operating the plant during the year 1914. For the present we are giving below a condensed statement for the unit cost of generating power for the two half years of 1914.

	First Six Months	Last Six Months	Saving, Per Cent
Operation	0.576	0.501	13.02
Production	0.685	0.545	20.43
Production average, preceding year.	0.723	.....	24.62

During the month of December plans were prepared and arrangements completed to start stocking of a coal pile for emergency use. Originally it was expected that this pile would be formed from the coal delivered in cars in order to take advantage of the lower freight rate on rail deliveries but as it developed the facilities for unloading frozen coal from unsuitable cars were inadequate and the cost of handling coal per ton reached 43 cents, and though blasting frozen coal with dynamite in the cars and handling same manually without expensive operation by Brown hoist reduced the cost of handling over 40 per cent, it was found more advisable to stock the coal delivered in boats. This has been actually done at a cost not exceeding 10 cents per ton piled.

"*Graphic Records.* The two sheets of performance record for December present a clear picture of the progress of manufacturing, and in this connection it should be noted that the variation of the ratio of pounds of coal per kilowatt hour during the last two months were considerably less pronounced than heretofore, which will undoubtedly be attributed to the greater care exercised in the boiler room routine. The total output during December was 9,703,000 kilowatt hours with a machine factor brought up as high as 83.5 per cent average, yet the peak load factor dropped to 48.7 per cent as against 51.8 per cent in November, but practically duplicated the condition of October when same was 48.6 per cent.

"*Comparison.* The comparison of our costs with other plants for November on the compiled tabulation of the comparative statistics of various power plants interchanging costs for mutual

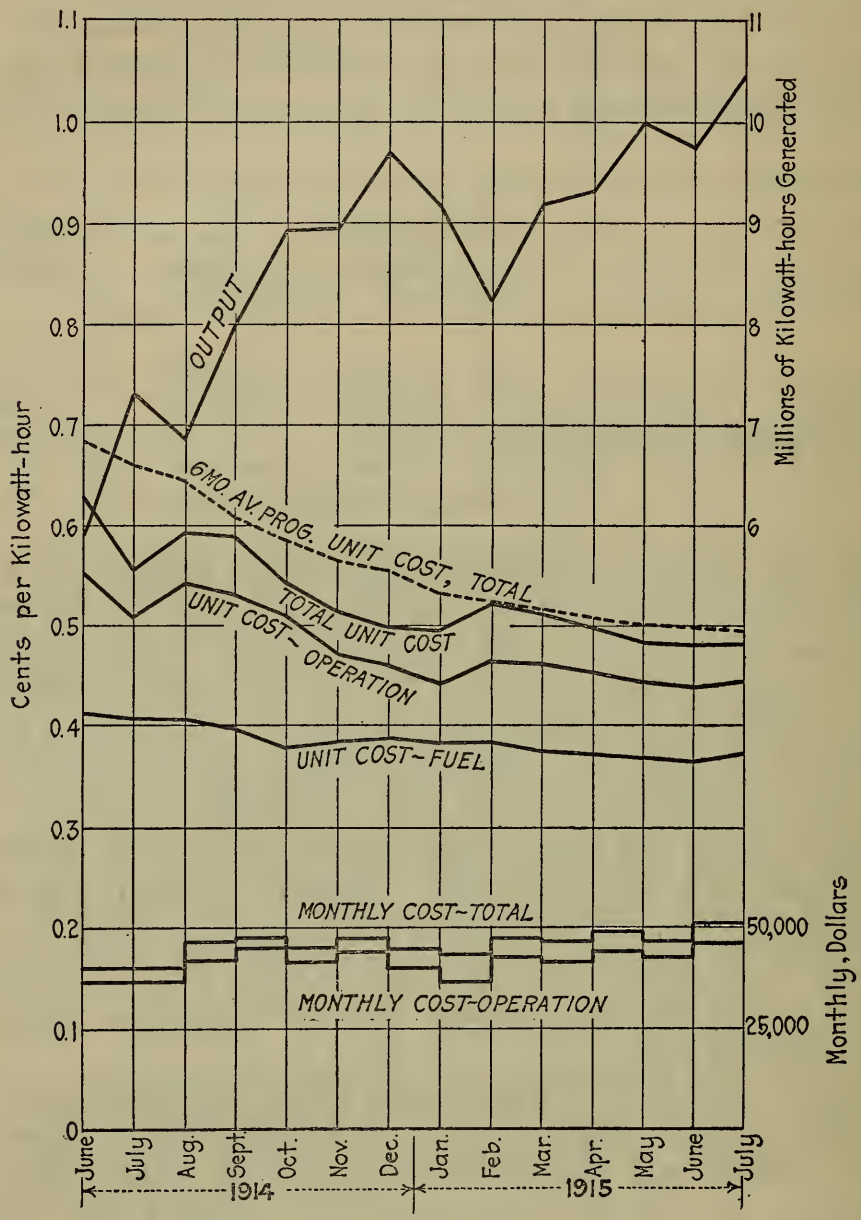


FIG. 125.—GRAPHIC COST RECORD

Seven items of operating records are charted on one card to four different scales; Time, Unit Cost Monthly Expense and Monthly Output. (Electr. R. R.)

information, shows that during the month of November we have climbed from the last place on the sheet outranking in the cost of manufacturing electric power the two other well known power plants."

For the purpose of visualizing expenditures incurred for a period of time and of studying general trend, temporary deflections, deviations from appropriations and similar purposes, a graphic chart of expenses should be kept in the superintendent's or chief engineer's office. One of the most convenient ways is to keep each item on a separate card, cross section ruled to a convenient scale of value ordinate and time on abscissa. Each

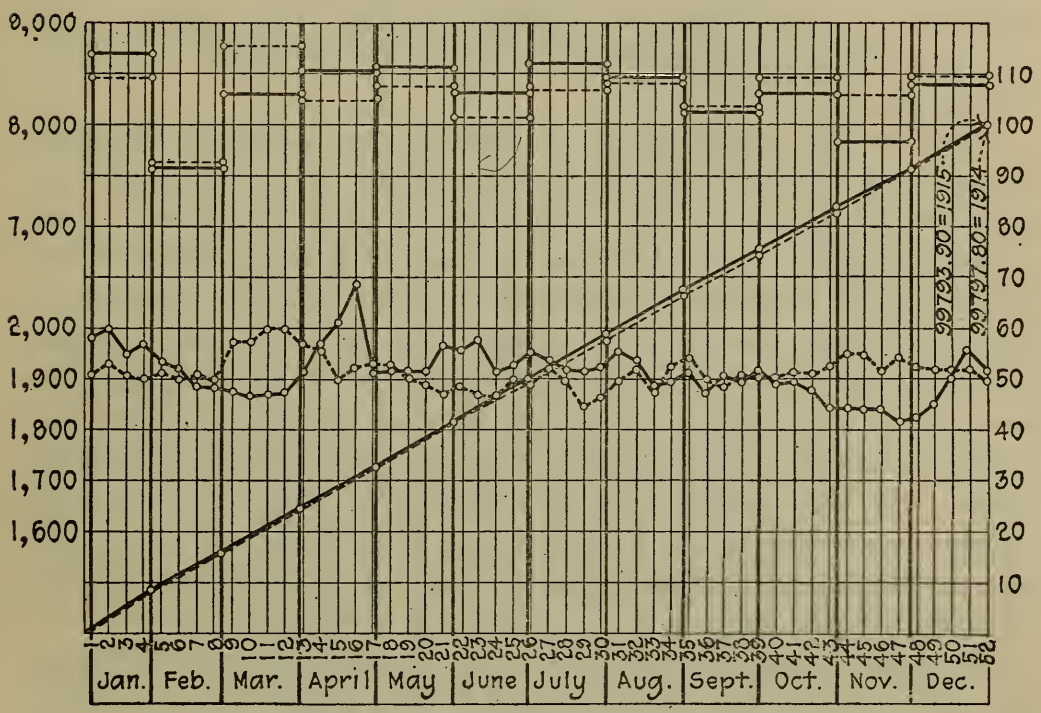


FIG. 126.—GRAPHIC COST RECORD CARD

The chart represents expenses of management and supervision for two consecutive years. During 1914 the management was carried along the old-fashioned lines without planning, without record keeping or cost keeping, whereas in 1915 all mechanism advocated by the author had been installed and put into use. Managerial overhead expenses, however, did not increase, as the change was substantially that of substituting useful analysis work for useless arbitrary bossing.

card drawn in this manner should have at least two curves—one of total expense for each period and another the expense per unit produced (unit cost). It is frequently necessary to supplement this basic information by reference curves such as cumulative or progressive total, appropriation, output, efficiency, and the like. It is never advisable, however, to plot curves of several years on the same monthly or weekly scale as such comparison, in order to be made intelligently, and be of service requires references to many other variable conditions or specific

changes that may not be remembered at a glance. Examples of such expense record cards are given in Figures 114, 125 and 126, the last having additional interest inasmuch as it compares, contrary to the statement just made two years of operation of the same plant. During the first year on record the plant had no organized office, kept no records, did no planning of work, had an insufficient office force and most of the planning and directing work was done on the operating floor on the spur of the moment by men having no suitable training for analyzing the circumstances and administering affairs by tradition and trusting in good luck.

During the next year these defects were radically stopped. A planning engineer and statistician added to the force as well as a stenographer, records were kept in most complete details, costs carefully analyzed, planning done in graphic form, storeroom service organized, maintenance work watched, laboratory analyses made, tests carried out, training given in hygiene, and first-aid offered to the employees, etc. Yet as it may be seen from the expense chart the amount of money spent for "administration" varied but by a few dollars from the preceding year. At the same time the operating cost per kilowatt hours was reduced 24 per cent and the total production expense (including rearrangement, repairs and maintenance) decreased 19 per cent.

In cases where the standard cost or ideal expenses are predetermined in a manner discussed in this chapter, the expense charts can be easily supplemented by a graphic relation of actual expenses to a standard allotted. Figures 127 and 114 plainly show how much in this case the record gains in clearness. The vertical bars drawn from the bottom of the chart go as high as the allotted ideal cost should be; the distance of the actual curve from the tops of these bars affords a measure of unnecessary expenses. Furthermore in spite of unprecedented high expense per 1,000 pounds of steam (as in May, 1917, on chart reproduced), comparsion with the standard virtually shows that the ideal conditions were almost attained, the high cost being due to the high price of coal, efficiency being only within 0.5 per cent of the expected boiler and grate efficiency of the plant, whereas a year ago (May, 1916), the actual expense being about 8 cents lower per 1,000 pounds of steam on account of cheaper purchase price of coal yet this was with only 50.25 per cent of boiler and grate efficiency.

On the other expense chart we see a rapid progress in approximating the ideal predetermined cost in certain items of operating expense. With an average monthly output of 109,000 kilowatt hours the monthly expense in 1913 and early in 1914 was nearly $600, giving a unit cost approximately $0.0055. The

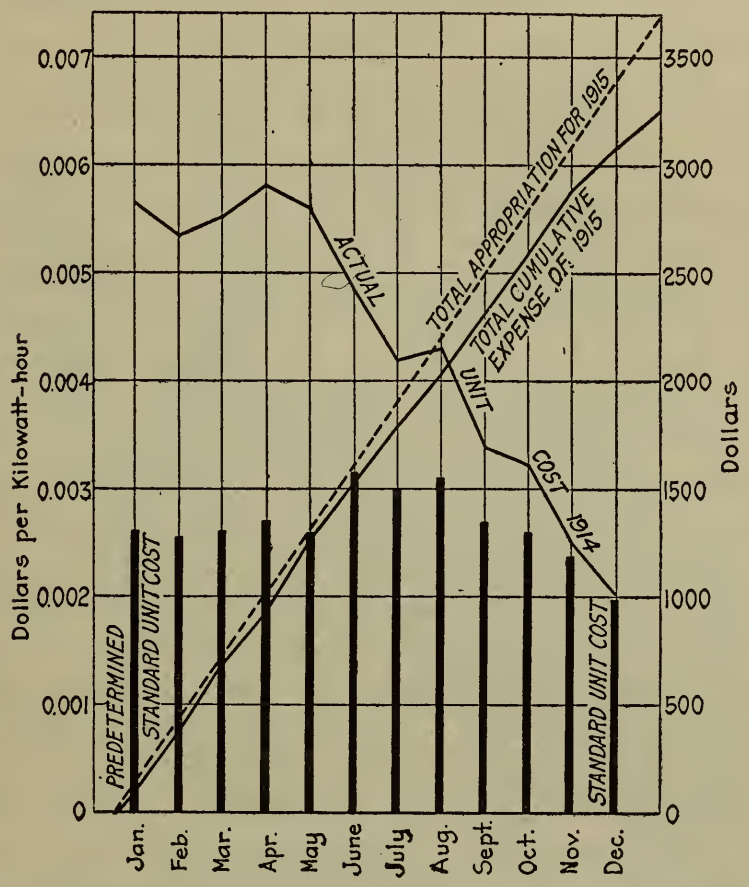


FIG. 127.—GRAPHIC RELATION BETWEEN ACTUAL AND STANDARD COSTS

Pre-determined standard costs per unit of output is represented by the height of bars drawn for each month. The distance of curve of actual unit cost from the top of the bars represents the over-expenditure, which in the first five months of the year, was over 100%, while in the last half of the year, less than 25%. In December the actual unit cost was practically that of pre-determined standard. The appropriation which would have been insufficient if operation were as inefficient as it was in the first half of the year, actually was not exhausted because of the rapid improvement in the elimination of waste.

appropriation for the next year, 1915, however, was made not of $7,200 but only half as big, namely $3,600 while actually only $3,241 were expended by December of the recorded year the actual expenses were already lowered to the level of ideal and during 1915 average unit cost was less than $0.003 as against an average of $0.0055 of 1913.

Cost of Purchased Power

In a number of cases where power is generated the cost reports are frequently used as a basis for deciding whether it is economical to continue generation of one's own power or greater advantages could be secured from a purchase of energy from a public utility company. This subject again permits of a dual analysis; first whether there are any advantages from a financial standpoint and second whether such a change offers any opportunity for national fuel conservation. The fuel administration after considerable studies arrived at the conclusion that in such establishments where steam is used for processes no advantages could be expected from a purchase of electric power parallel with the local generation of steam. The reasons for this under the existing conditions are obvious—the thermal losses of steam after passing through engines or high-pressure turbines are not great and exhaust steam may be used for many purposes even in preference to live steam. Financially likewise there could be no advantage of discarding one's own generating equipment as the labor charge is insignificant and sometimes even irreducible, while boiler-room labor, supplies and repair usually remain unchanged and coal consumption decreased only a few per cent.

In cases where heating during the winter months is the only use of the exhaust steam, or where the exhaust steam has no application, the matter is getting more complicated and each case should be decided on its own merits. In such instances accurate cost keeping is of inestimable value and frequently wrong steps are taken because of the lack of reliable cost data and operating records. Undoubtedly, in many cases of this kind a coöperation between the central station service and the isolated plant is the most desirable solution of the problem both from a financial and a conservation viewpoint. During the period when heating is needed, central stations have heavy loads and should not care to add to their peaks while the isolated plant, utilizing the exhaust steam could attain very high economy. On the other hand, when no heating is required the isolated plant in a general case becomes wasteful and the purchase of electric service is desirable, while central stations with decreased summer demands should appreciate the opportunity to improve their load and machine factor, reduce idleness, and obtain other obvious advantages from seasonal consumers. Yet, moved by motives beyond the scope of this chapter such seasonal serv-

ice is usually refused by the public utilities and some public service commissions failed to reach a decision favorable to the

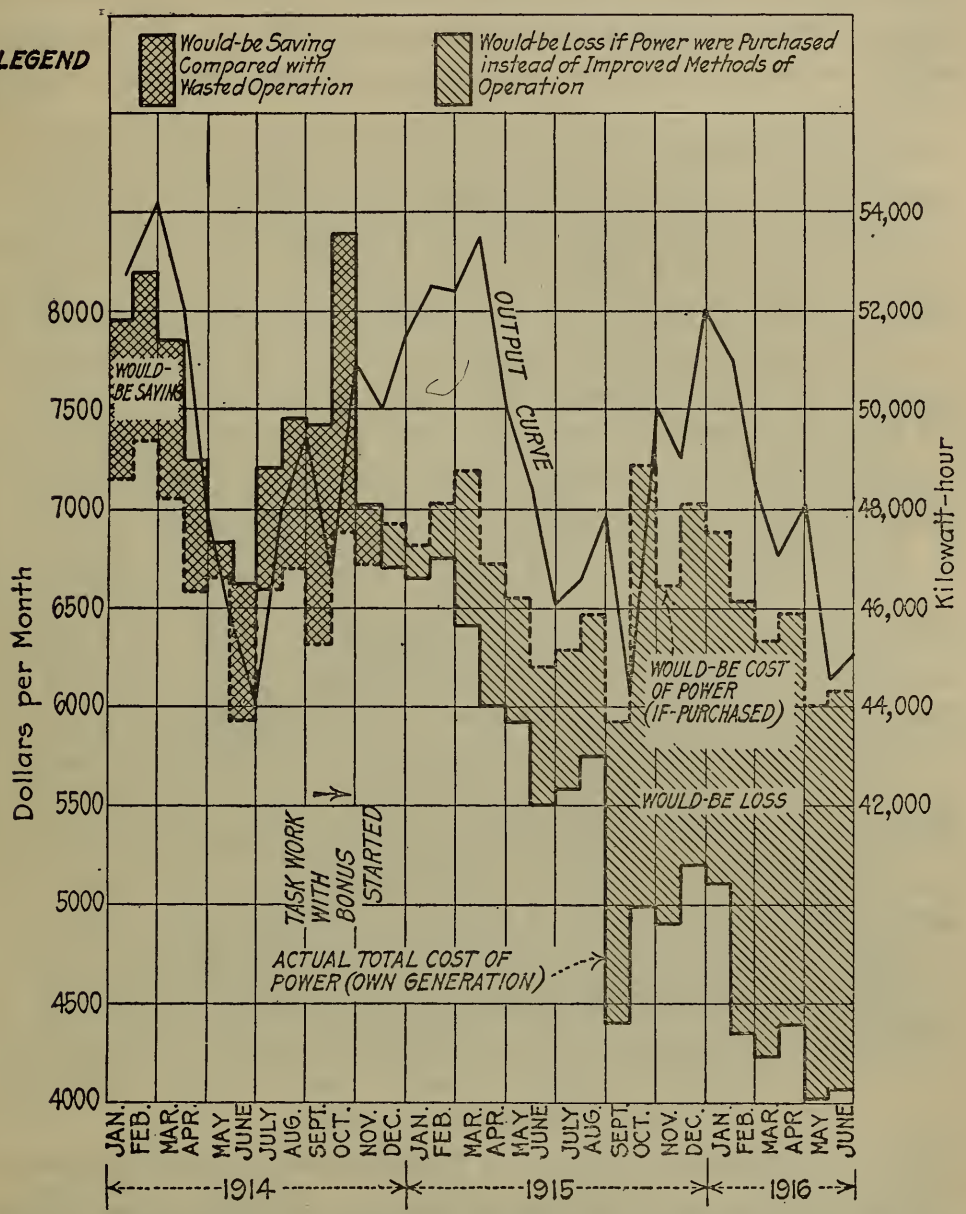


FIG. 128.—COMPARISON OF PROMISED SAVING AND ACTUAL COSTS

The rates for purchased electric power appear very favorable when compared with the operating cost of a poorly managed plant. When instead of purchasing electricity from outside, methods of management and operation were bettered, the offered rates proved to be far in excess of the actual operating expense. No credit has been allowed for the use of exhaust steam.

public and beneficial for the fuel conservation. Small isolated plants working purely for light or power are seldom warranted economically or financially. Inefficient equipment as compared

with central stations, heavy overhead or small output, liability for breakdowns and similar handicaps are generally so pronounced that replacement of such plants by Central service is the most advisable course readily disclosed by a cost analysis. Yet a serious limitation inherent in the very nature of ordinary cost keeping

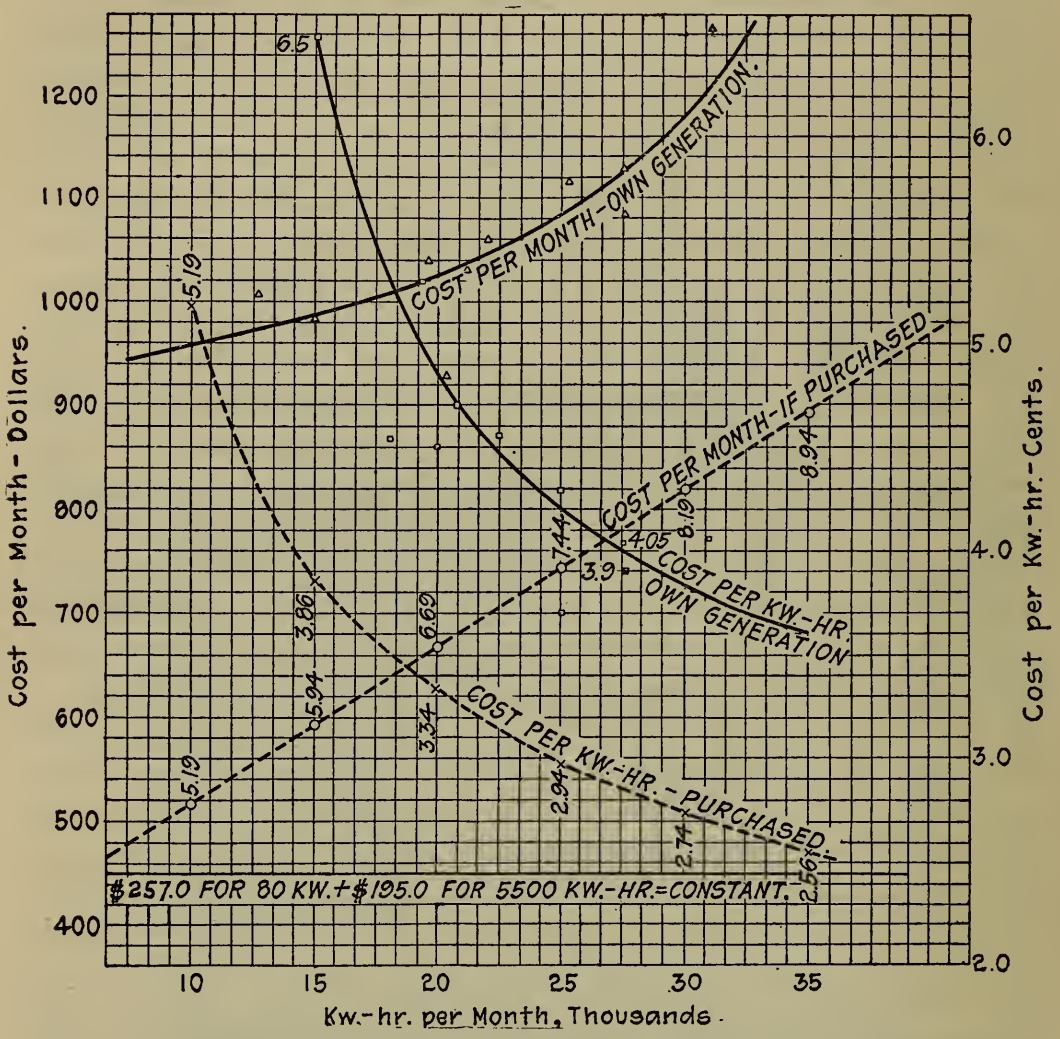


FIG. 129.—COMPARISON OF COSTS OF PURCHASED AND GENERATED POWER

In a small plant at the passenger station requiring practically no heat a distinct advantage was secured by purchasing electricity for illumination. (Actual record.)

becomes in such cases glaringly apparent. Unless it is known that the expenses were as low as they could be under best managerial methods, the comparison of electric service rates with mere cost records is liable to cause a very serious loss. By way of illustration let us examine Figure 128.

A New England public utility company offered to replace an isolated plant service by purchased energy. Their report

showed $750 saving a month over the poor record of the isolated plant. When, however, the method of management and the operating practice of this isolated plant were modernized along the lines advocated by us, the central service, if accepted, would have meant an annual loss of about $18,000. Not less common example may be found in the case of an isolated lighting plant in Boston where considerable efforts have been spent to improve the operating economy and reduce the expenses. Eight months operation disclosed that with 15,000 kilowatt hours monthly output the expenses per kilowatt hour were 6.5 cents and with 30,000 kilowatt output about 3.8 cents whereas these quantities of energy could have been purchased from the public utility company in the first instance at 3.86 cents per kilowatt hour and in the second at 2.74 cents per kilowatt hour. On the average consumption a saving thus appeared to be 1.43 cents per kilowatt hour or $3,500 per year. The relations between rates, unit costs, monthly expenses and consumption are shown in Figure 129.

Again, in cases of a parallel operation of the isolated plant with the public utility supply many specific problems will arise. They may be pointed out by a cost accountant but explanations and remedies should be sought from engineering research. The four column tabulation that follows, illustrates a typical situation developing in the plant of a transportation company during the month when public service current was switched into their lines. The first line represents expenses for independent operation during the first part of the month and the second line the expenses of generating the balance of one's own current during the parallel operation. The summary and the average for the whole month shows clearly the effects.

Independent Operation	Labor	Material	Total	Unit Cost
	Dollars	Dollars	Dollars	Cents
1. From 1st till 20th.....	3912.55	223,739.35	27,651.90	0.42599
2. During 20th to 31st.....	2363.60	11,135.60	13,499.20	0.56494*
3. Entire month, average.....	6276.15	34,874.95	41,151.10	0.46339

* During this period the plant was operating in parallel with the public utility central station from which the 1,511,200 kilowatt hour, were purchased during these ten days.

More light may be thrown on this situation by Figure 130. The thermal efficiency of the plant due to decreased demand

and poorer machine factor has dropped from an average of 9.2 per cent to 7.1 per cent, indicating an increase in coal consumption per kilowatt hour of 0.8 pound or nearly 3,000 more tons of coal per month. To offset this loss not financially but economically is an impossibility for a central station service as no power house can generate one kilowatt hour of energy on 0.3 pound of coal.[121]

From the above examples we are now warranted in drawing a conclusion: all financial statements and cost accounts in order to be of help to improve the conservation of natural resources and to increase the productive efficiency must be prepared or at least scrutinized and digested by an expert in economic production, that is, a specially trained engineer. Similarly in cases of contemplated discontinuation of an inefficient isolated plant, of the purchase of power from outside, of a parallel operation and so forth, it is the task of the engineer to find:

1 Whether existing mode of plant operation cannot be improved and what is the possible ultimate economy of it

2 What effect the substitution or parallel operation will produce on (a) expenses and (b) national fuel economy

3 What results may be expected from a change on service, on men, on the community, etc.

This obviously involves besides other studies and tests a very careful examination of the terms of the proposed contract for the purchase of power. By way of illustration we represent graphically in Figure 130 the terms of a large power contract (40,000,000 kilowatt hour per year minimum) as described several years ago in many technical papers[122] thus: "The contract under which power is supplied to the railroad provides for primary and secondary charges the maximum demand is 65,000 kilowatt with a minimum load factor at this demand 70 per cent; a minimum power factor for single phase service except momentarily 70 per cent. For loads above the minimum demand the limit of load factor is 50 per cent, etc." How uniform is the final billing charge per kilowatt hour consumed, due to the various stipulations of this contract, is apparent from our diagram, though in a mere reading of the contract an impression may be gained that the scale of rates is sliding and other advantages offered.

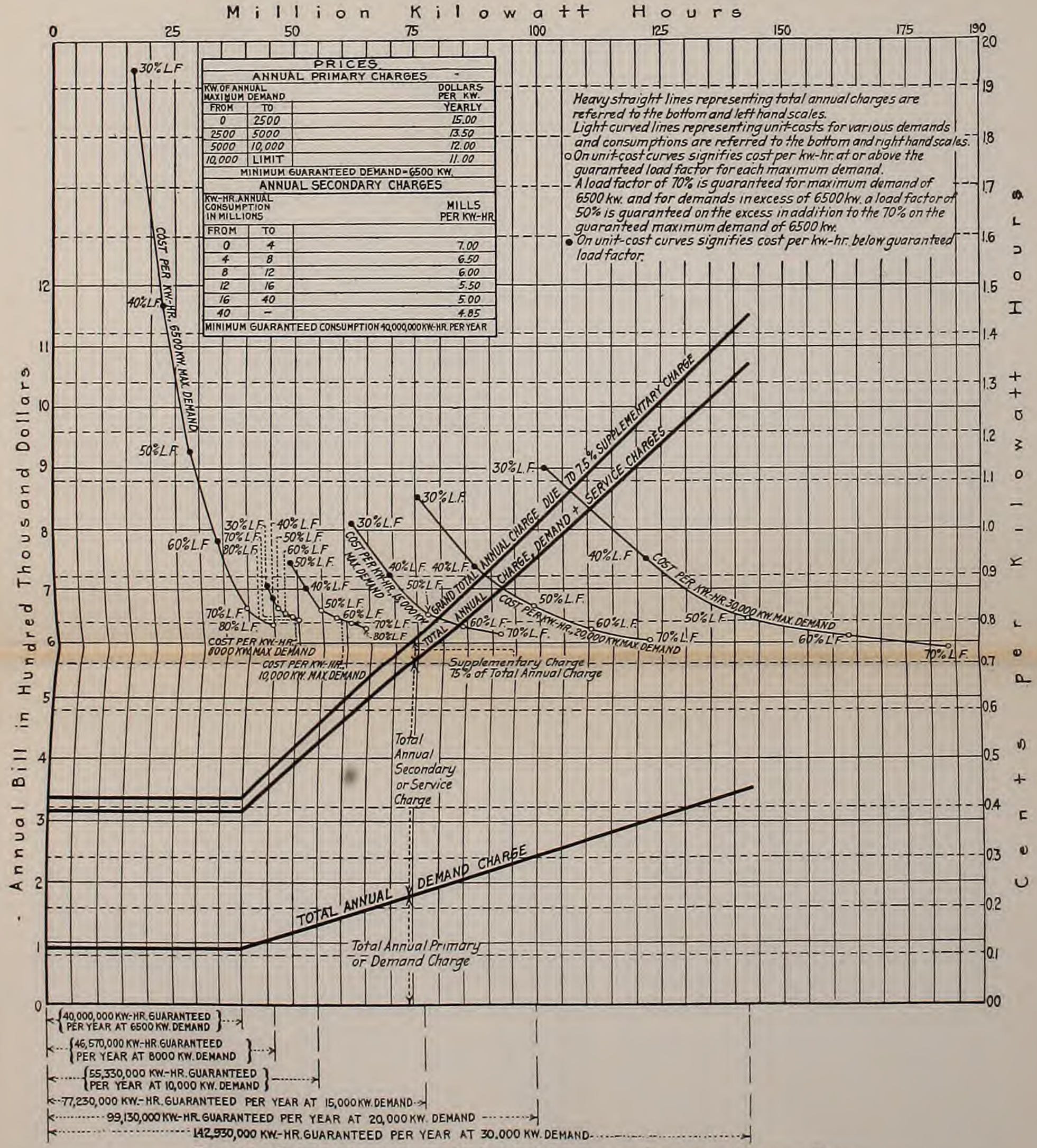

Million Kilowatt Hours
0
25
50
75
100
125
150
175
190
PRICES
ANNUAL PRIMARY CHARGES
KW. OF ANNUAL MAXIMUM DEMAND
FROM
TO
DOLLARS PER KW. YEARLY
0 2500 15.00
2500 5000 13.50
5000 10,000 12.00
10,000 LIMIT 11.00
MINIMUM GUARANTEED DEMAND = 6500 KW.
ANNUAL SECONDARY CHARGES
KW-HR. ANNUAL CONSUMPTION IN MILLIONS
FROM
TO
MILLS PER KW-HR
0 4 7.00
4 8 6.50
8 12 6.00
12 16 5.50
16 40 5.00
40 – 4.85
MINIMUM GUARANTEED CONSUMPTION 40,000,000 KW-HR. PER YEAR
Heavy straight lines representing total annual charges are referred to the bottom and left hand scales.
Light curved lines representing unit-costs for various demands and consumptions are referred to the bottom and right hand scales.
o On unit-cost curves signifies cost per kw.-hr. at or above the guaranteed load factor for each maximum demand.
A load factor of 70% is guaranteed for maximum demand of 6500 kw. and for demands in excess of 6500 kw. a load factor of 50% is guaranteed on the excess in addition to the 70% on the guaranteed maximum demand of 6500 kw.
• On unit-cost curves signifies cost per kw.-hr. below guaranteed load factor.
Annual Bill in Hundred Thousand Dollars
Cents per Kilowatt Hours
30% L.F.
40% L.F.
50% L.F.
60% L.F.
70% L.F.
80% L.F.
COST PER KW-HR. 6500 KW. MAX. DEMAND
COST PER KW-HR. 8000 KW. MAX DEMAND
COST PER KW-HR. 10,000 KW. MAX. DEMAND
COST PER KW-HR. 15,000 KW. MAX. DEMAND
COST PER KW-HR. 20,000 KW. MAX. DEMAND
COST PER KW-HR. 30,000 KW. MAX. DEMAND
GRAND TOTAL ANNUAL CHARGE DUE TO 7.5% SUPPLEMENTARY CHARGE
TOTAL ANNUAL CHARGE, DEMAND + SERVICE CHARGES
Supplementary Charge 7.5% of Total Annual Charge
Total Annual Secondary or Service Charge
TOTAL ANNUAL DEMAND CHARGE
Total Annual Primary or Demand Charge
40,000,000 KW-HR. GUARANTEED PER YEAR AT 6500 KW. DEMAND
46,570,000 KW-HR. GUARANTEED PER YEAR AT 8000 KW. DEMAND
55,330,000 KW-HR. GUARANTEED PER YEAR AT 10,000 KW. DEMAND
77,230,000 KW-HR. GUARANTEED PER YEAR AT 15,000 KW. DEMAND
99,130,000 KW-HR. GUARANTEED PER YEAR AT 20,000 KW. DEMAND
142,930,000 KW-HR. GUARANTEED PER YEAR AT 30,000 KW. DEMAND

FIG. 130.—GRAPHIC ANALYSIS OF TERMS OF CONTRACT FOR PURCHASED ELECTRIC POWER

Diagram analyzes the cost of power at which it may be purchased on the contract in question, according to load factor, demand, consumption, etc.

Chapter XI

POWER AS A COMMODITY

THE success or failure in mastering power production determines the future of society, the rise and fall of nations, the form, order and ideals of our relations. Upon those who are called to organize, plan, direct, and control production, depends whether wastefulness, idleness, and friction shall ruin such a state of affairs, or efficiency, industry, and coöperation lead us to a higher form of social order. Which way will be chosen in this or that case is not a matter of free choice, but an inevitable resultant of an interplay of a large number of social and economic forces. Those who are clearly gaining in the game of the destruction of natural resources, benefiting by idleness, and unable to foresee the outcome of the dissipation of human resources through a low standard of life and its corresponding ills—will, by the sheer logic of facts cling to and support privileges and competition. So long as the control of production rests in their hands, it is not the fact of the destruction of human and natural resources, but the figures of the ledger account that determine their attitude toward the conservation of life, fuel, material, and time.

Again, those industrial leaders who have enough foresight, either intuitive or based on a study of economic facts and tendencies, to get a clear vision, or who for reasons of patriotism or in anticipation of future advantages, are ready to denounce the unrestrained scramble for individual gain at whosesoever and whatever expense, come out strongly in favor of coöperation and the abolition of special privileges, and wisely practice efficiency on a plan broader than any one plant, any one branch of industry, or even any one state. Their method of mastering production is thus permeated by the democratic spirit—since it is guided from without and based on facts forming the foundation of the economic structure of society—*coöperation.*

Having described in the preceding chapters a method of mastering power production based on the application of science to a democratically conducted industry we shall now attempt to appraise in general the effects of securing in this manner an adequate and cheap supply of power, produced with the greatest economy in fuel and human energy.

Ancient Greek civilization was sustained by the servile Helots, each

family having on an average five Helots who supplied a great part of the Greek energy. The modern American family has at its service one hundred and fifty servants in the form of electrical, mechanical, and hydraulic energy harnesses to carry on the production of the necessities of our mode of living. To produce this amount of power, at least 150,000,000 horsepower must be generated, or in other words, to produce our average output of commodities, without the aid of power plants, the working population of the United States would have to be not less than three billion men.

The prevalent imperfect methods of utilizing our power producing plants are at the same time appalling: an average small plant or steam locomotive makes use of only 5 per cent of the energy consumed while with a more perfect installation a three times greater return is possible; with our crude, unscientific, and haphazard management we fail to utilize more than probably 60 per cent of the energy delivered from the existing equipment. To-day an American worker has, on an average nearly two horsepower available to aid his production, almost twice as much as the working man of Great Britain; an American miner produces two or three times as much coal as does his English fellow, yet our lead in standard rates of wages, average purchasing power of an individual and productivity as indexed by the cost of the necessities of life is proportionally small, for the two horsepower installed does not deliver all the power it can, for out of a ton of coal 800 pounds are wasted in the plant, some unnecessarily consumed by the railroad hauling it to the plant, and only an insignificant amount of the by-product is recovered and a financial burden accumulates on the lavishly installed but only partially utilized power generating equipment. On the basis of the prices prevailing in 1915, the loss, which could be made available under the present state of technical knowledge and recoverable under a constructive economic policy, is estimated by the Smithsonian Institute (Bulletin 102, vol. 1) at $2,000,000,000 annually. Correcting this figure for present prices and adding the losses due to needless bulk transportation, poor methods of management, and wasteful utilization of developed power we arrive at a figure approximating six billions of dollars per year, meaning a loss of $60 per capita.

In this sense the manufacture of power is a most fundamental industry and one upon which the whole economic structure of our civilization depends. The problems related to better management of power production are paramount in importance to any other single industrial problem, while the product—energy—becomes the basic commodity indispensable to the existence of modern society.

FIG. 131.—MAN-POWER DEVELOPMENT APPLIED TO IRRIGATION

In Japan even to-day this practice is in vogue. This form of power is strictly localized and limited to operator.

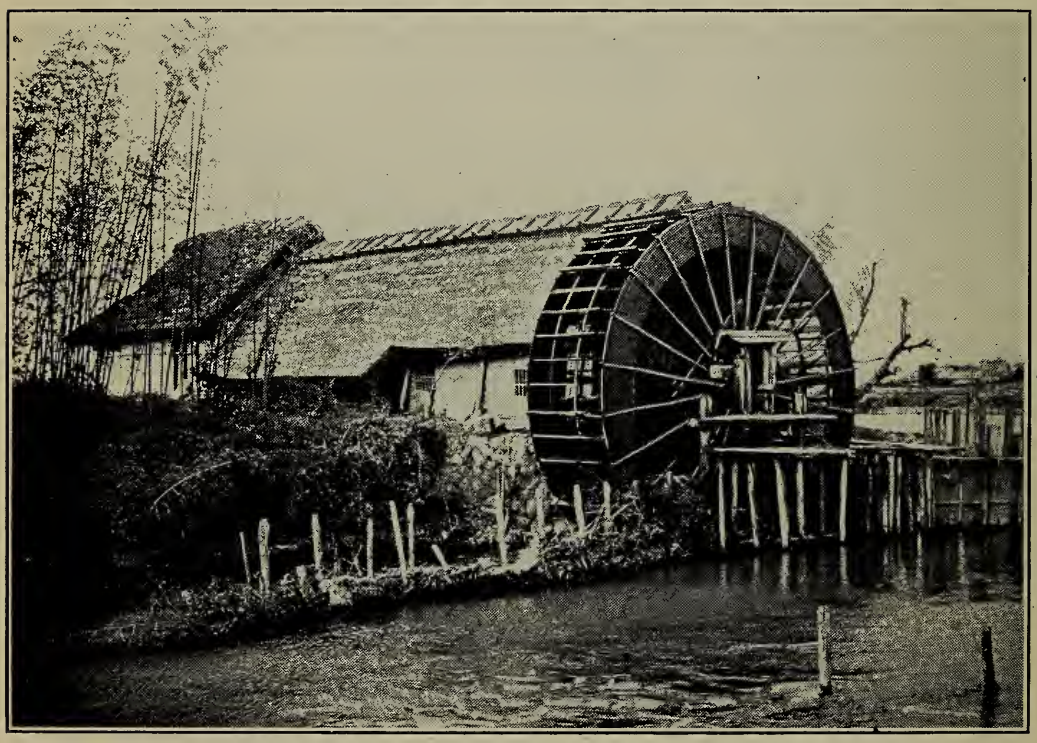


FIG. 132.—PRIMITIVE WATER-POWER DEVELOPMENT

Together with wind mills, water wheels are the first conquest of man's brain power over the free energy in nature. Mechanical power developed is also utilized locally.

Historical Review

The advent of power as the most potent factor of the cultural development of a people must be briefly reviewed before the immediate problems and future aims can be clearly grasped and constructive efforts properly directed.

The history of the progress of mankind from the Promethean fire and arts of Hephaestos, down to modern industry, is the story of the development of power and its application to man's use. Through the ages up to the eighteenth century, stretched the period of the primitive knowledge and use of power. This period, of wind and water, is marked by the limited, local and individual character of its industries. (See Figures 131 and 132.)

When men learned to liberate the energies of coal and use the power of steam as a motive force, the old world order passed away and the so-called "industrial revolution," a hundred years ago, ushered in the formative period of modern industry and the new world order dawned.

The use of steam, freed power from geographic restrictions inherent in hydraulic power, opened the coal fields and the oil wells, and created and developed transportation and industry as they are to-day.

The United States consumes over one-half of the world's oil production and 52 per cent of the total output of coal—two-thirds of that coal being used for power production, and the remaining one-third for coke, domestic use, etc. Coal forms one-third of the total freight hauled in the United States and more than one million men are engaged in mining coal and oil.

The present industry has been developed on the basis of the distributive use of coal. Although the possible expansion of industry is unlimited, the means of bringing to it energy in the material form of coal requiring a relatively enormous and superfluous bulk, has well nigh reached the limit of transportation capacity, and as only 6 per cent, in rare cases as much as 15 per cent, of the energy contained in coal is available from the fuel, a fuller and more complete utilization of coal has become imperative. This situation signals practically the end of the formative period of industry, and the opening of the reign of the new motive force—electricity. (See Figures 133, 134 and 135.)

Electricity, virtually energy itself, not locked up in ponderous matter, has the capacity to work freed from substantial form, devoid of bulk, practically abolishing time in its transmission, and to a great

extent distance, capable of subdivision and distribution, easy of application and adaptable to a vast range of utilization.

All of these capacities and characteristics make it possible to measure, buy, sell, distribute and use "energy," whereby "power" takes its place as a commodity. With the coming in of this commodity human industry in all its branches entered the era of unlimited possibilities.

Electricity which as a motive power was first applied to portable machinery and the locomotive has become the driver in numberless devices: in mines, for pumps, ventilators, coal-cutters, drills, crushers, hoisting machines, transportation, etc.; in the iron and steel industry, for the refining of steel and iron, making steel directly from the ore, welding, cutting metal, etc., the electric motor replacing more and more the steam engine, in textile mills, flour mills, pulp and paper mills and mills of every kind. It is gradually replacing steam because of the greater safety and ease of handling on the farm not only for tractors and other machinery and irrigation, but as a stimulant for increasing the crops—a usage of electricity that has been the subject of a considerable study, nitrogen fertilizers obtained by fixing the nitrogen of the air by electricity; its limitless potentialities in electrochemistry; its magic use in communication; its use in transportation; in short, though electricity, within the brief period of its advent as a practical factor, has been put to such varied and extended usages, the incalculable realm and scope of its application are but just beginning to be grasped. Table 1 showing the horsepower used per wage earner in various industries of the United States during 1914 illustrates the intensity and the extent of power application. The following figures, covering the development of central power stations in the United States, also show the rapid increase in the use of electric energy in the form of power and light.

The electric energy generated for sale in 1907 was 10,621,407,000 kilowatt hours; in 1912, 17,585,622,000 kilowatt hours; and in 1917 it was about 27,000,000,000 kilowatt hours, which shows an increase of 155 per cent over the production in 1907. Figure 136 illustrates the growing consumption of electrical energy in the United States in recent years.

The figures published by the United States Bureau of Statistics for 1917 are for central light and power stations. The number of central stations was 6541, of which 4224 were commercial and 2317 municipal. These had a total primary horsepower of 12,857,998 (8,389,398 steam engines, 217,186 internal combustion engines, 4,251,423 water-wheels) with a dynamo capacity of 9,001,872 kilo-

TABLE I—HORSE-POWER USED PER WAGE EARNER IN VARIOUS INDUSTRIES DURING 1914

	Number of Wage Earners	Total Primary Power, HP.	Horse-power per $1,000 of Product	Total Power per Wage Earner	
				Primary, HP.	Electrical, HP.
Agricultural implements	48,459	121,428	0.73	2.5	1.7
Artificial stone products	10,255	20,326	0.92	1.9	0.6
Automobile and bodies	127,092	173,684	0.26	1.4	1.0
Boots and shoes, including cut stock and findings	206,088	112,929	0.19	0.5	0.3
Boots and shoes from rubber	18,687	24,621	0.45	1.3	0.3
Boxes (fancy and paper)	45,311	38,179	0.51	0.8	0.5
Brass, bronze and copper products	40,306	122,700	0.75	3.0	1.6
Bread, bakery	124,052	107,771	0.21	0.9	0.6
Brick, tiles and pottery	127,444	470,758	2.53	3.7	0.7
Butter, cheese, and condensed milk	23,059	130,862	0.35	5.7	1.0
Buttons	14,511	14,398	0.69	1.0	0.3
Canning and preserving	74,071	120,004	0.79	1.6	0.4
Carpets and rugs	31,309	29,486	0.42	0.9	0.8
Carriages and wagons	52,391	112,549	0.78	2.1	0.9
Cars and general shop construction (electric railroads)	26,384	44,989	1.16	1.7	1.7
Cars and general shop construction (steam railroads)	339,518	433,994	0.82	1.3	0.9
Cars, steam railroad, not included above	54,288	126,687	0.65	2.3	2.1
Cement	27,916	490,402	4.81	17.5	12.0
Chemicals	32,311	282,385	1.52	8.7	5.3
Clocks and watches	23,328	15,647	0.48	0.6	0.4
Clothing, men's	225,719	53,281	0.11	0.2	0.1
Clothing, women's	168,907	28,396	0.05	0.2	0.1
Coke, not including gas-house coke	21,107	120,327	1.21	5.7	4.2
Confectionery	53,658	55,823	0.32	1.0	0.7
Copper and tinsheeting	80,029	75,263	0.79	0.9	0.6
Cordage and twine	27,326	93,937	1.57	3.4	1.2
Corsets	20,496	7,057	0.17	0.3	0.2
Cotton goods	393,404	1,585,953	2.29	4.0	1.3
Cutlery and tools	33,427	73,255	2.86	2.2	1.0
Dyeing and finishing	48,467	130,172	1.19	2.7	1.0
Fancy articles	10,967	8,005	0.45	0.7	0.2
Fertilizers	22,815	114,281	0.74	5.0	2.8
Firearms and ammunition	18,557	18,828	0.45	1.0	0.9
Flour mills and grist mills	39,718	822,384	0.93	20.7	3.7
Food preparations	20,306	80,022	0.36	3.9	2.3
Foundry and machine-shop products	564,610	1,129,768	0.82	2.0	1.5
Furniture and refrigerators	133,498	251,997	0.89	1.9	0.6

HORSE-POWER USED PER WAGE EARNER IN VARIOUS INDUSTRIES DURING 1914—*Continued*

	Number of Wage Earners	Total Primary Power, HP.	Horse-power per $1,000 of Product	Total Power per Wage Earner	
				Primary, HP.	Electrical, H.P.
Gas illuminating	43,792	245,715	1.11	5.6	0.9
Glass	74,502	163,139	1.33	2.1	1.2
Gloves, leather	10,668	3,357	1.15	0.3	0.1
Hats	21,318	20,851	0.55	0.9	0.4
Hosiery, knit goods	150,520	125,842	0.48	0.8	0.3
Ice	23,011	461,988	7.64	20.0	2.2
Iron and steel, blast furnaces	29,356	1,222,273	3.84	41.6	7.2
Iron and steel, rolling mills	248,716	2,706,553	2.94	10.9	4.8
Iron and steel, bolts and nuts	10,658	28,897	1.23	2.7	1.7
Iron and steel, forgings	10,689	38,215	1.13	3.5	2.3
Jewelry	28,289	15,666	1.19	0.5	0.4
Leather, tanned	55,456	122,712	0.47	2.2	1.3
Lime	12,429	39,134	2.12	3.1	1.0
Lumber products	618,163	2,796,902	2.78	4.5	0.5
Marble and stone	54,981	207,461	1.93	3.7	1.7
Mattresses	11,747	21,674	0.55	1.8	1.3
Millinery	45,274	12,736	0.11	0.3	0.1
Mineral waters	15,506	25,164	0.43	1.6	0.7
Musical instruments	37,556	44,349	0.47	1.2	0.5
Oil, cottonseed cake	21,810	249,781	1.17	11.5	1.4
Paint and varnish	16,083	70,611	0.48	4.4	2.2
Paper, wood pulp	88,457	1,621,154	4.88	18.3	3.6
Patent medicines	25,502	28,872	0.28	1.1	0.7
Paving materials	19,540	138,026	3.58	7.1	2.7
Petroleum	25,366	128,468	0.32	5.1	1.5
Rubber goods	50,220	151,927	0.67	3.0	1.8
Sewing machines	18,007	24,229	0.88	1.3	1.0
Shipbuilding	44,489	115,333	1.30	2.6	1.4
Silk goods	108,170	116,924	0.46	1.0	0.4
Slaughtering	101,076	260,996	0.15	2.6	1.2
Smelting and refining copper	17,731	194,980	0.44	10.9	4.9
Soap	14,172	35,737	0.27	2.5	1.2
Stoves and furnaces	37,325	49,150	0.54	1.3	0.8
Sugar refining	11,253	49,666	0.17	4.4	2.1
Tobacco	178,872	38,737	0.07	0.2	0.1
Turpentine	34,817	2,478	0.11	0.07	0.0
Typewriters	11,091	10,887	0.44	0.9	0.6
Wire	17,600	83,940	1.02	4.8	2.2
Wire work	12,126	21,547	0.51	1.7	1.1
Wood	11,615	43,334	2.27	3.7	0.4
Woolen goods	163,976	398,367	1.01	2.4	0.8

watts and a station output of 25,438,611,417 kilowatt hours. The number of stationary motors served was 554,817 with a total of 9,266,323 horsepower, 256,838 being lamps and 1,389,882 incandescent lamps.

A number of electric traction companies, 1,311, operating 44,811.53 miles of single tracks, consumed 12,187,850,831 kilowatt hours of which 4,947,348,042 kilowatt hours were purchased and 7,240,501,789 were generated by the railroads themselves with a dynamo capacity of 2,928,454 kilowatts and 4,200,192 primary power (3,543,915 steam, 28,294 internal combustion, oil and gas, and 629,983 water power).

The census of manufactures for 1914 gives the following figures concerning the use of primary power, the use of electric power, and the degree of electrification of the manufacturing industry in per cents of the total primary power:

Industry	Degree of Electrification of Manufacturing Industries				
	Primary Power	Electric Power Motor Installation	Electric Motors Operated by Purchased Current	In Per Cent of Primary Power	
				Run by Current Generated in Plant	Unelectrified Primary Power
1. Iron and steel	5,544,542	2,651,350	14.2	33.6	52.2
2. Lumber	3,240,411	448,511	7.2	6.8	76.2
3. Textiles	2,737,369	995,637	16.5	19.9	63.6
4. Paper	2,057,984	671,999	20.2	12.5	67.3
5. Food	1,994,983	643,391	19.0	13.2	67.8
6. Miscellaneous	1,583,616	818,303	22.0	29.8	48.2
7. Chemicals	1,503,376	594,095	22.7	16.8	60.5
8. Stone, glass, clay	1,490,975	675,642	24.2	21.0	54.8
9. Non-ferrous metals	575,925	320,153	26.5	29.1	44.4
10. Liquors	575,769	155,864	10.0	19.3	70.7
11. Railroad repair shops	479,983	369,724	29.1	40.0	22.9
12. Vehicles	454,917	327,705	39.5	32.5	28.0
13. Leather	317,887	151,694	22.6	25.2	52.2
14. Tobacco	38,757	21,555	30.4	25.3	44.1
Total	22,547,574	8,843,142	17.4 (over)	21.9 (over)	60.7 (over)

Electric energy is generated either by the use of fuels or by waterpower, and in accordance with the source it is designated as either carboelectric power or hydroelectric power. At present the hydro-electric power production is equal to the use of about 40,000,000 tons of coal, whereas over 400,000,000 tons are yearly consumed to produce steam power and carboelectric power (27,000,000 tons for the latter).

The following table taken from The Energy Resources of the United States (Bulletin 102, vol. 1, Smithsonian Institute), shows the distribution of potential water power, of unmined coal and tapped oil, in percentage of the total resources in the United States, with special regard to sections lacking in coal.

States	Water-power, Potential, %	Coal Reserve, Unmined	Oil Reserve Untapped %
Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut.....	3	none	none
Delaware, Virginia, Maryland, South Carolina, Georgia, Florida.....	6	1% (Va. and Maryland)	none
Arizona, New Mexico, Texas, Arkansas, Oklahoma, Louisiana....	6	4%(Texas & Oaklahoma)	52
California, Oregon, Washington...	43	2% (Washington)	31
Other States of the Union.....	42	93%	17

The total water-power developed at present in the United States amounts to about 6,000,000 horsepower of which about 4,500,000 is commercial power. The potential water-power is estimated at about 200,000,000 horsepower of which about 20,000,000 is capable of immediate development. Fifty million of the above mentioned total potential water-power could be used without special provisions for storage. About 10 per cent of the ready available water-power, and 3 per cent of the total open to development under elaborate arrangements for water sotrage has been developed.

It is estimated that the water-power readily available in the United States if converted into electric energy is more than capable of turning every industrial wheel and illuminating every street and building throughout the republic.

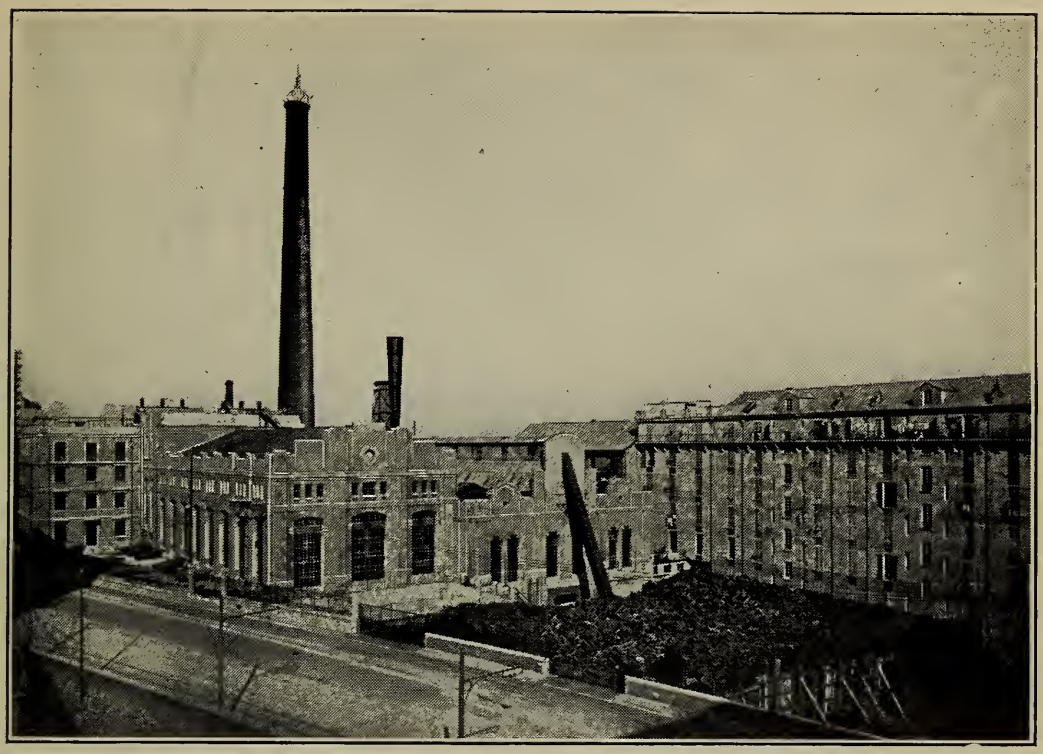


FIG. 133.—AN EXAMPLE OF A THERMAL POWER PLANT

A typical European central station with adjoining workingmen's barracks on the right, offices on the left and fuel yard in the foreground.

FIG. 134.—AN EXAMPLE OF ELECTRIC DISTRIBUTING SUBSTATION

A Typical European substation feeding two-phase current to electric railroad.

The figures showing the production of coal and coke, and the current generated by steam in the various States of the United States form an interesting comparison, which may be seen in the Tables II and III.

TABLE II

PRODUCTION OF COAL AND COKE IN 1916, IN SHORT TONS

	Coal	Coke
Alabama	16,250,000	4,250,000
Arkansas	2,000,000	.....
California	12,000	.....
Colorado	10,260,948	1,320,000
Georgia	140,000	25,000
Illinois	63,500,000	2,500,000
Indiana	18,738,256	3,100,000
Iowa	7,600,000	.....
Kansas	8,000,000	.....
Kentucky	25,106,500	980,000
Maryland	4,930,000	395,000
Massachusetts	.....	600,000
Michigan	1,056,393	.....
Minnesota	.....	250,000
Missouri	4,000,000	.....
Montana	3,688,307	.....
New Mexico	3,893,185	479,153
North Dakota	620,000	.....
Ohio	30,500,000	725,000
Oklahoma	3,053,543	.....
Oregon	39,230	.....
Pennsylvania (bituminous)	170,270,000	30,746,000
Pennsylvania (anthracite)	88,312,000	.....
South Dakota	14,000	.....
Tennessee	6,589,915	275,000
Texas	2,300,000	.....
Utah	3,621,935	224,294
Virginia	9,300,000	700,000
Washington	3,000,000	140,000
West Virginia	87,989,000	1,900,000
Wyoming	7,650,000	2,300,000
	582,435,212	50,909,447

In the other set of data recently compiled by the United States Geological Survey for January, 1920, we see the relation of the output by Hydroelectric and carboelectric plants (see Table IV), and the quantities and kinds of fuels consumed in the production. (See Table V.)

TABLE III—CURRENT GENERATED BY STEAM AND SHORT TONS OF COAL BURNED BY STATES

	1917	
	Kw-Hr.	Coal
Alabama	202,000,000	303,000
Arizona	8,000,000	12,000
Arkansas	63,000,000	95,000
California*	.....	.....
Colorado	316,000,000	474,000
Connecticut	179,000,000	268,000
Delaware	39,000,000	59,000
District of Columbia	179,000,000	268,000
Florida	78,000,000	117,000
Georgia	116,000,000	174,000
Idaho †	.....	.....
Illinois	2,070,00,000	3,105,000
Indiana	700,000,000	1,050,000
Iowa	185,000,000	278,000
Kansas	142,000,000	213,000
Kentucky	229,000,000	343,000
Louisiana	163,000,000	245,000
Maine	100,000,000	150,000
Maryland	358,000,000	537,000
Massachusetts	1,200,000,000	1,800,000
Michigan	329,000,000	493,000
Minnesota	232,000,000	348,000
Mississippi	58,000,000	87,000
Missouri	772,000,000	1,158,000
Montana	17,000,000	26,000
Nebraska	147,000,000	220,000
Nevada †	.....	.....
New Hampshire	62,000,000	93,000
New Jersey	640,000,000	960,000
New Mexico	9,000,000	14,000
New York	3,350,000,000	5,025,000
North Carolina	50,000,000	75,000
North Dakota	19,000,000	29,000
Ohio	1,459,000,000	2,188,000
Oklahoma	100,000,000	150,000
Oregon	293,000,000	439,000
Pennsylvania	1,895,000,000	2,843,000
Rhode Island	191,000,000	286,000
South Carolina	60,000,000	90,000
South Dakota	10,000,000	15,000
Tennessee	158,000,000	237,000
Texas	315,000,000	473,000
Utah	76,000,000	114,000
Vermont	31,000,000	46,000
Virginia	227,000,000	340,000
Washington	579,000,000	869,000
West Virginia	113,000,000	169,000
Wisconsin	349,000,000	524,000
Wyoming	18,000,000	27,000

*Coal consumption for generating electric power is practically nothing.
†Coal consumption for generating electric power is negligible.

TABLE IV—PRODUCTION OF ELECTRIC POWER AND CONSUMPTION OF FUEL BY PUBLIC UTILITY POWER PLANTS IN THE UNITED STATES IN JANUARY, 1920

Thousands of Kilowatt-Hours Produced

State	By Water Power	By Fuels
Alabama	34,864	14,452
Arizona	8,567	11,703
Arkansas	132	7,675
California	164,727	112,346
Colorado	12,784	22,811
Connecticut	9,069	59,256
Dealware	.....	6,807
District of Columbia	.....	23,317
Florida	965	10,890
Georgia	43,816	10,696
Idaho	48,574	1,348
Illinois	14,831	260,723
Indiana	2,943	91,788
Iowa	55,574	31,622
Kansas	1,741	35,986
Kentucky	.....	23,409
Louisiana	.....	18,126
Maine	23,381	1,577
Maryland	284	31,261
Massachusetts	22,009	147,936
Michigan	51,799	138,180
Minnesota	28,053	36,157
Mississippi	.....	5,886
Missouri	5,720	54,082
Montana	89,574	562
Nebraska	909	20,436
Nevada	3,416	119
New Hampshire	4,322	5,166
New Jersey	143	101,478
New Mexico	53	1,524
New York	227,033	382,108
North Carolina	53,035	10,956
North Dakota	.....	2,732
Ohio	1,490	258,432
Oklahoma	217	17,287
Oregon	32,278	7,845
Pennsylvania	45,324	329,392
Rhode Island	355	37,114
South Carolina	61,911	5,825
South Dakota	477	3,327
Tennessee	39,443	9,233
Texas	74	55,397
Utah	13,932	.....
Vermont	15,430	786
Virginia	13,801	30,423
Washington	103,981	4,480
West Virginia	1,775	95,306
Wisconsin	35,443	37,451
Wyoming	152	4,785
Total	1,274,401	2,580,198
Total, by water power and fuels	.....	3,854,599

Authority: Division of Power Resources, U. S. Geological Survey.

How insignificant is as yet the development of public utility service may be conceived from the fact that during 1919 only 7.6 per cent of total bituminous coal produced in the country was used in central stations, or about 35,000,000 tons out of nearly 460,000,000 tons produced.

As it has been stated before, the power production in this country —steam and carboelectric power together—consumes nearly 400,000,000 tons per annum.[124] The moving of this quantity requires about 10,000,000 car loads at 40 ton car capacity. In 1917 there were in the United States 950,000 coal cars in use. In addition there was also to be moved about 160,000,000 tons of coal for house-heating and coke making purposes, the transportation of which requires another 4,000,000 cars.

In March, 1918, C. E. Stuart, of the Utilities section of the Conservation Division, U. S. Fuel Administration said: "The individualistic way in which fuel is now consumed in cities is not efficient. A ton of coal burned in a large central station will produce at least four times as much electric power as if burned in the average small plant. . . . There are localities in the country where there is an excess of hydroelectric energy and where there are at the same time coal-burning central stations. The saving that could be effected by shutting down the coal consuming plants . . . is evident. . . . the hydroelectric plants would carry the load of the coal consuming plants . . ."

If it takes 15 tons of coal to generate one electrical horsepower per annum, then the 20,000,000 horsepower of water-power at present not used but economically immediately available for the generation of electric power, represent about 300,000,000 tons of coal, which could be saved thereby, relieving the means of transportation, which would then not be taxed above their capacity and not less than 132,000,000 tons at the rate allowed for the present development, will not have to be transported.

In spite of the growing use of electricity, practically no change has been effected in the basic inefficient conversion of coal into available energy and only a small fraction of the available water-power has been developed, although electricity has rehabilitated the use of water power, making available for generating purposes both sources of power: coal and water. Yet in this competition it would appear that fuel is the winner.

The public utilities corporations may not see the use of an extra effort to develop special water-power sources, even if ultimately the power generation proves to be cheaper, as cheaper power production

FIG. 135.—ELECTRIFIED RAILROAD LINE IN EUROPE

Coal problem in Italy is so acute that the railroads had to be electrified.

TABLE V

The production of the electric power shown in Table IV required the combustion of fuels in the quantities indicated in the following table:

State	Coal, Short Tons	Petroleum and Derivatives, Barrels	Natural Gas, Thousands of Cubic Feet
Alabama	29,211	1,255	.....
Arizona	198	42,473	.....
Arkansas	8,675	4,888	155,222
California	.....	545,829	179,563
Colorado	43,345	110	.....
Connecticut	77,311	4,374	10,236*a*
Delaware	9,139	.....	.....
District of Columbia	23,237	.....	.....
Florida	2,425	54,753	.....
Georgia	21,179	19,605	.....
Idaho	150	10	.....
Illinois	411,719	472	.....
Indiana	205,453	254	2,025
Iowa	94,185	576	.....
Kansas	39,710	91,428	76,283
Kentucky	45,149	188	.....
Louisiana	7,589	60,528	68,510
Maine	3,410	49	.....
Maryland	39,552	.....	1,500
Massachusetts	173,088	1,764	.....
Michigan	180,542	139	.....
Minnesota	64,060	620	.....
Mississippi	14,028	11,841	.....
Missouri	91,997	90,657	.....
Montana	4,206	22	1,257
Nebraska	37,926	16,503	.....
Nevada	367	842	.....
New Hampshire	6,768	.....	.....
New Jersey	156,280	136	280*a*
New Mexico	4,733	866	.....
New York	478,533	763	72,579
North Carolina	21,992	34	.....
North Dakota	19,362	150x	.....
Ohio	401,066	697	161,065*b*
Oklahoma	8,353	71,940	275,926
Oregon	190	3,657	.....
Pennsylvania	532,761	5	49,937
Rhode Island	35,196	7,560	.....
South Carolina	11,779	.....	.....
South Dakota	7,729	1,936	.....
Tennessee	22,729	25	.....
Texas	58,707	211,222	48,227
Utah	3	.....	.....
Vermont	1,748	2,146	.....
Virginia	43,212	132	.....
Washington	10,396	15,612	.....
West Virginia	106,230	50	227,900
Wisconsin	64,626	544	.....
Wyoming	14,418	4,217	3,300
Total	3,634,662	1,270,872	1,333,810

(*a*) Artificial gas. (*b*) Includes 61,520 artificial gas.

would cause them to impose upon the public utilities a correspondingly lower sales rate for power. The public can always be relied upon to pay any kind of rate price so long as the actual production is sufficiently high in cost to prevent the rate from appearing extortionate. This explains the fact that many public utilities, instead of using 2 or 3 pounds of coal sufficient for the generation of one kilowatt hour burn as much as 10 pounds of coal for that purpose. Why then, they argue, lower the cost of production, as the gain in doing so would be only for the public at large—and the public does not count—a reasoning patent in frequent appeals to courts of justice for the protection of public rights, illustrated in the case of Covington and Lexington Turnpike Company vs. Sanford (164 U. S. 578), where the court said: "A corporation is not entitled as of right and without reference to the interests of the public, to realize a given percent upon its capital stock. Stockholders are not the only persons whose rights or interests are to be considered. The rights of the public are not to be ignored. The public cannot properly be subjected to unreasonable rates in order simply that stockholders may earn dividends."

Nowhere is the situation better seen than in the rate schedules of many central stations, where the small (or residential) consumer has to bear the burden, special prices being made to large industrial consumers,—to discourage them from generating their own power. The large wholesale consumer is practically able to make his own terms, a position not enjoyed by the general public.

Prospective Review

For over twenty years a controversy has been going on in the United States between the advocates of central stations and those of private or isolated plants, as to the most economic means of power supply. The respective merits of each of these systems have been put forward, certain salient points being acknowledged by both sides: that the central station or public utility field includes a host of establishments where the installation of isolated plants is not warranted; that the localized private (isolated) power plant is an economic necessity in certain types of buildings and manufacturing establishments where heat is of prime importance and the power production only a by-product; and that between those two well defined groups there lies a great majority of buildings and manufacturing establishments, which could be served by either or both of these methods of power supply.

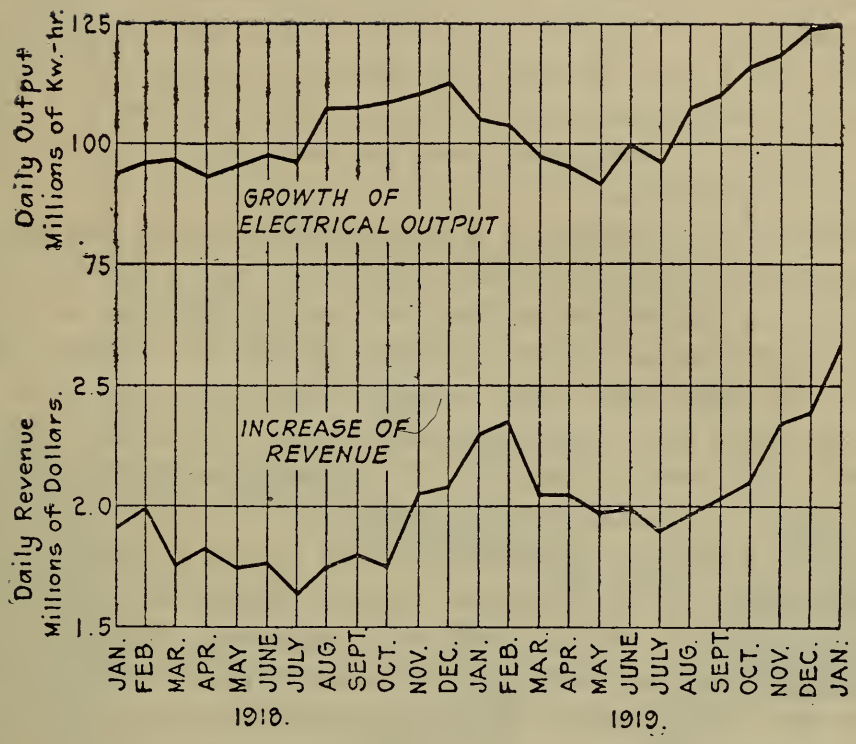


TABLE I—CENTRAL-STATION RETURNS FOR TWELVE MONTHS

	Percentage of Installed Capacities Represented	Revenue from the Sale of Energy			Percentage of Installed Capacities Represented	Kw.-Hr. Output		
		1919 Thousands	1918 Thousands	Per Cent Increase		1919 Thousands	1918 Thousands	Per Cent Increase
Mar.	45	$28,579	$24,447	17.3	45	1,359,296	1,340,210	1.0
Apr.	45	27,740	23,919	16.0	45	1,279,274	1,240,782	2.9
May	45	27,795	24,291	15.5	45	1,306,622	1,314,206	—1.0
June	47	28,175	24,701	14.1	47	1,399,951	1,367,908	2.3
July	44	25,794	22,568	14.1	44	1,309,301	1,281,874	2.0
Aug.	54	32,756	29,006	13.0	54	1,801,836	1,793,706	0.5
Sept.	53	32,344	28,336	14.0	53	1,761,582	1,695,862	4.3
Oct.	55	35,492	30,077	18.0	60	2,175,636	1,987,004	9.0
Nov.	53	37,439	31,927	17.2	58	2,055,428	1,895,693	8.2
Dec.	59	44,125	37,978	16.0	65	2,509,571	2,270,833	10.0
		1920	1919			1920	1919	
Jan.	54	44,531	37,169	20.0	64	2,450,924	2,078,880	18.0
Feb.	*57	43,835	36,020	22.8	67	2,395,065	1,920,428	24.1

*Includes estimates for twenty-five companies, representing 6.2 per cent of the total installed capacity of all central stations.

FIG. 136.—GROWING CONSUMPTION OF ELECTRICAL ENERGY IN U. S. A.

Statistics of central stations indicate that even in post-war period the growth of electrical output is steady and rapid while the increase of revenue grows still faster.

This situation caused a third school to come forward and to advocate as a solution of the problem the making available of the commodity by a coöperation of central stations with isolated plants. To this school must be added the plan of a further utilization of the fuel by developing a central station service of heat and steam, which service in concurrence with gas, and electric current is in practice in some cities.

However the advocates of a central station supply and those of private isolated plants, and those who would find a solution of the problem in a coöperation of these two supply methods, as well as those who propose a further utilization of fuel by a central station service of steam and heat, concern themselves only with coal or oil as direct fuel, forgetting that at best only 15 per cent and generally only about 6 per cent of the energy content of coal is transformed into the commodity—power.

The two diagrams Figures 137 and 138 as prepared by Mr. Tryon of the U. S. Geological Survey, clearly illustrates both: purpose to which coal is used and staggering extent of losses sustained in its use, partly due to poor design of equipment and partly due to the neglect of the management to introduce better operating methods as set forth in the preceding chapters.

The distributive generation of electric power—as was and had to be the case for steam power—was a practical procedure only so long as the use of electricity was small and restricted, but electric power is to-day a commodity increasing in demand. The issue therefore is that of a general power problem and not one of hydro-electric power or carboelectric power, or of central stations or isolated plants. Transmission lines of several hundred miles are common to-day and longer transmissions are being developed, hence the question is: whether it be more advantageous to transport generated power, or to transport energy in bulk, that is, fuel to generate the power at or near the place of consumption.

This question in itself indicates that the basis of the problem is economy in material and human effort, which requires the fullest utilization of the sources of energy. With units of the highest type and largest capacity little more than 15 per cent of the heat of the fuel can be converted into a salable product as power in the form of electric energy. Most installations however do not deliver half as much of the energy of the coal as a commercial product.

Coal besides being energy in material and bulky form, is also the source of innumerable mineral products of great social value. More than one thousand coal products as vital to the community

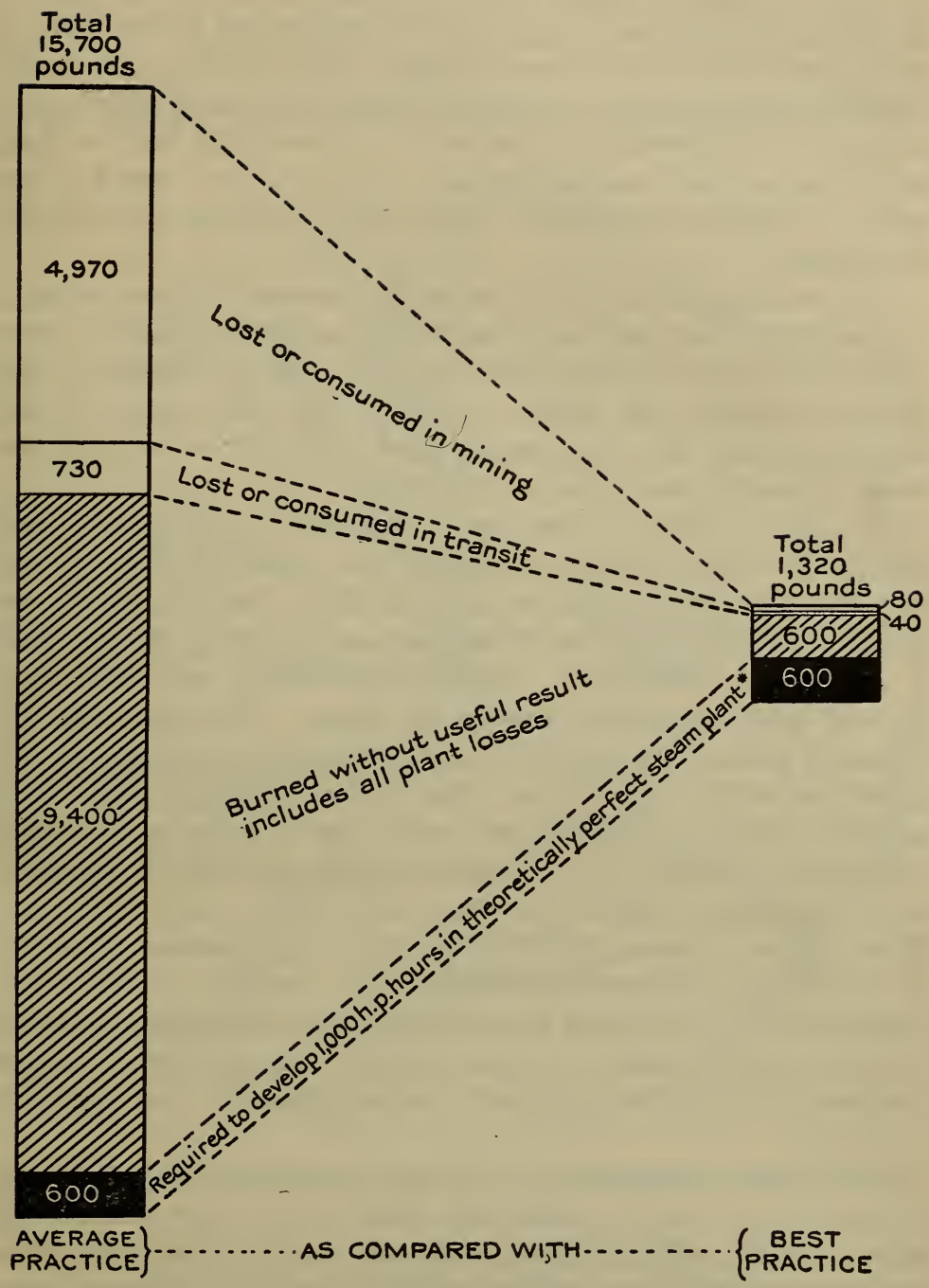


FIG. 137.—AVERAGE AND BEST PRACTICE IN COAL UTILIZATION

To develop 1,000 horsepower hours, a theoretically perfect steam engine and boiler would require about 600 pounds of coal. Actually under ordinary practice we mine or destroy perhaps 15,700 pounds of coal in the seam in order to develop the 600 pounds worth of energy. The best practice does the same work with about 1,320 pounds of coal. In other words, the best practice uses only a tenth or a twelfth as much as the average.

Of this only about 200 pounds is finally converted into mechanical energy.

Data from Bureau of Mines and Super-Power Survey.

as fuel are to-day in use. The full utilization of the whole range of values, including energy, to-day still transported in the form of coal, imposes itself in the near future. This utilization, at present confined to the coke and gas industry which can still be described by the term of "by-product production" as it takes only half the field, must broaden itself and become an economic force covered by the term of "multiple production." There lies the future and the only great future.

The meaning of multiple production becomes apparent when it is remembered that one ton of bituminous coal gives on the average 10,000 cubic feet of illuminating (or fuel) gas, 20 pounds of ammonium sulphate, 2½ gallons of benzol and 8½ gallons of tar, which represent only the primary products, while other chemicals, drugs, dyestuffs, etc., could be extracted.[125]

In 1918 the price of one ton of bituminous coal, at the mine, was $1.32 yet the multiple products of the same ton of coal would have had a collective value of at least $16. The illuminating gas and the benzol are: one a perfect fuel and the other an equivalent of gasoline as motor-fuel. Multiple production will make both gas and benzol important sources of power. Moreover, with the advent of industrial alcohol as fuel we shall not forget that gasoline cannot be mixed with alcohol, while it can be mixed with benzol and such mixture of gasoline and benzol can be mixed with alcohol, offering an excellent fuel for internal combustion engines. Furthermore, ammonium sulphate has great value both as an artificial fertilizer and as a source for the extraction of ammonia—serviceable for medicinal, refrigerating, cleaning, etc., purposes. Tar, as has been pointed out is not only road building and waterproofing material, but primarily is a basis of great coal-tar industry, one that gave Germany its industrial supremacy and advantages at the beginning of the war.

It has been estimated by the Fuel Administration that between 10 and 25 per cent of steam coal is at present wasted under the boilers. About 400,000,000 tons of coal in the United States are used to generate power, half of which is used by industry[126] and the other half is consumed by the transportation lines. Reckoning on the basis of only 12.5 per cent of saving unquestionably possible in every case merely by improved methods of management and operation of plants, intelligent mastery of power production will release for the country at least 50,000,000 tons of coal annually.

In primary coal products it represents a loss of about 250,000,000,000 cubic feet of gas, 500,000 tons of ammonium sulphate,

125,000,000 gallons of benzol, and 425,000,000 gallons of tar. In terms of cash the 50 million tons wasted in power production alone represent a price value of $200,000,000 at the colliery, while the multiple products value of this coal would be probably $1,200,000,000.

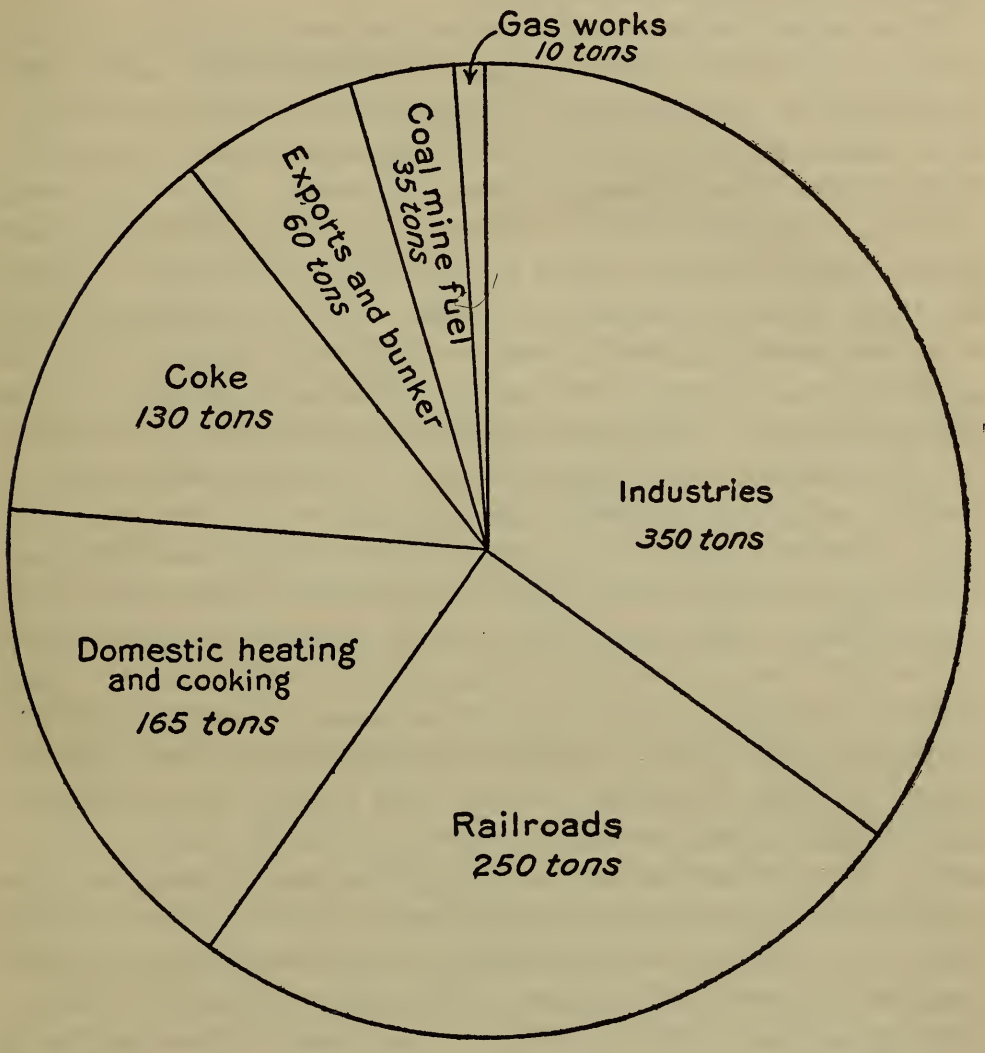


FIG. 138.—WHAT BECOMES OF OUR COAL—DISPOSITION OF THE MINER'S YEARLY OUTPUT

The average yearly output per man employed underground in America is about 1,000 net tons. The diagram shows the uses to which the 1,000 tons are put, including both anthracite and bituminous coal.

Though the application of electricity has made headway, multiple production has not yet been considered for general adoption, its importance not yet having been grasped. Yet both are the most important economic forces of moulding influence on the present and future industrial order. The principle of multiple production as an economic force is bound to cause a revision in popularly

accepted ideas of economics. Numerous plans are advocated offering solutions of the industrial power problem. The most radical solution involving the principle of multiple production is perhaps the plan advocated by the British Coal Conservation Committee, of which the following is an abstract:—

"The sub-committee of the Reconstruction Committee in Great Britain recommends that the present inefficient electric service system should be superseded by a comprehensive system divided into about sixteen districts, in each of which there should be one authority dealing with all generation and main distribution. Sites for electric generating purposes should be chosen on important waterways, outside not inside of towns. Plans to be prepared to construct on these sites large super-power plants, capable: (1) of supplying energy to a comprehensive electric power distribution system. (2) of supplying electric energy at lowest possible price for all processes and manufacture. Such plants should be designed so that, as methods are perfected for extracting by-products from fuel before using it for the purpose of production of electrical energy, the by-product plant can be combined with the power plant. Power available from surplus gas or waste heat should be turned into electrical energy in local plants, which should feed into the main distributing system. Coal which does not warrant transportation away from the mine should be used at the spot for power generation. With a view to carrying out this policy a board of commissioners should be appointed with the following powers: (*a*) to stop the extension or multiplication of uneconomical stations for public supply; (*b*) to arrange for the handing over on equitable terms of the generation, transmission, and main distributing system in each of the areas into which the country is to be divided; (*c*) to standardize for each area the frequency and voltage of the main transmission and distribution systems; (*d*) to select for each area the authorities to work under adequate control as regards limitation of dividends, etc."

Alternative types of electric organizations are described in an appendix. In reference to these alternative types the sub-committee emphasizes the need of initiative and resource in the management of electric service organizations and the freedom of range and keenness which are distinctive of a private enterprise, as such things are highly conducive to the best success. Such was the original outlines of a super-power central station plan based on coal as source of energy combined with the application of the principle of multiple production.

Recently Mr. C. M. Garland in the May 1920 issue of the *Journal,* American Institute of Electrical Engineers, reviewed the problems arising in this connection in America as follows: "In the United States where at least 500,000,000 tons of bituminous coal are burned annually, there are 10,000,000,000 gallons of tar and the equivalent of 30,000,000,000 pounds of ammonium sulphate, having a combined value of $2,500,000,000 burnt up with the coal. It is not practicable to save all of these by-products, but a recovery of 25 per cent could reasonably be expected when it is considered that 80 per cent of the coal mined is used by industrial plants, public-utility plants and the railroads.

"The remarkable part of all of this is that the means are at hand to-day and have been at hand for a number of years for carrying out the regional power development, the regional distribution of heat, the placing of every industrial load on the central station, the releiving of railroad congestion, particularly terminal congestion, through the reduction of the hauling of fuel, the reduction of the smoke nuisance in cities, and, in addition to these, the recovery of the by-products from at least 25 per cent of the coal mined.

"I refer to the combination of the well-known Mond by-product system of gas generation with the low-temperature distillation of coal.

"In the Mond process coal is gasified in a special producer whereby the coal is converted into gas, tar, and ammonia. The ammonia is recovered in the form of ammonium sulphate, which amounts to from 50 to 100 pounds per ton of coal gasified and has a value of about four cents per pound under present prices. The value of this by-product, therefore, varies from $2 to $4 per ton of coal gasified, depending upon the amount recovered.

"The tar recovered from the straight Mond process represents about 6 per cent of the weight of the coal, and this tar consists principally of pitch which has little or no value.

"The gas from the Mond process has a calorific value in the neighborhood of 140 B. t. u. per cubic foot and from 65 to 70 cubic feet of gas are obtained per pound of coal. This gas can be burned under boilers with greater efficiency than the coal and without smoke. It is also suitable for use in the firing of house-heating boilers and for small or large industrial furnaces.

"This gas can be piped economically within a radius of fifteen miles of the central station. This distance limits the size of the central station and to a certain degree does not accomplish everything that could be desired from regional power and heat distribution.

It does, however, relieve railroad-terminal congestion, and it will in a large measure relieve main-line congestion, owing to the greater economy in the use of fuel and to the elimination of fuel hauled for the use of railroads."

In Smith's process, the coal to be carbonized is first crushed and then delivered to primary retorts, where it is distilled at temperatures between 500 deg. to 900 deg. F. The result of this first distillation is a reduction of volatile contents of the coal to about 8 per cent and a large yield of tar and gas of high B. t. u. value.

This devolatilized coal is again ground, mixed with pitch obtained from tar recovered in the process, and briquetted. Briquettes are made subject to an additional distillation at a higher temperature of about 1800 deg. F., resulting in the production of carbo-coal and the recovery of by-products in far greater quantities than in ordinary by-product coke ovens. Clinchfield, Va., coal, in carbonizing 1000 tons produced:

1. Carbo-coal briquettes (over 13,000 B. t. u.)	725 tons
2. Sulphate of ammonia	20,000 to 25,000 lbs.
3. Other nitrogen products, pyridine bases up to	4,000 oz.
4. Motor spirits (benzol, 250 gals. toluol, 500 gals. others, 1,000 gals.)	1,750 gals.
5. Crude tar acids (cresylic)	4,040 "
6. Water white naphthas	3,500 "
7. Creosote oil	5,450 "
8. Heavy creosote oil	4,660 "
9. Surplus gas of about 530 B. t. u.	2,000,000 cu. ft.

The overloading of our railroad with coal, constituting over 30 per cent of all rail freight is now responsible for the limitation of coal output from the mines, which according to the United States Geological Survey is in 1920 less than 50 per cent of the full-time output. Relief of the railroads is necessary, and the electrification of railroads offers a solution. Specific limitations however to a plan of steam-electric and hydroelectric super-power stations are seen in that.

In the same article quoted above Mr. Garland writes: "In the central and northern portions of the United States every industrial plant from seven to eight months out of the year requires fuel for heating. In 75 per cent of these plants the fuel required for heating is more than sufficient to generate the power required for manufacturing operations. For practical purposes it may therefore be considered that the power is obtained during these months with-

out fuel expenditure. This explains why only 30 per cent of the industrial plants buy their power. Of this 30 per cent 20 per cent would doubtless be better off if they had efficiently operated plants and generated their own power. The writer is a strong advocate of central station development, but believes that it is well to recognize the limitations imposed by existent conditions."

"The great barrier . . . is therefore the fact that the average plant can take advantage of the increased economy of the central station only from four to five months out of the year. During the winter season the same amount of coal would have to be hauled to furnish heat in so far as the industrial plants are concerned. The amount of coal hauled would therefore be reduced only by the amount of coal saved by the electrification of the railroads which in this section would not amount to more than 20 per cent of the total. The writer, therefore, cannot see any great relief to railroad congestion unless some method of heating other than direct-coal firing is resorted to. It is also this coal for heating that leads to the overcrowding of railroad terminals during the winter months. Again, it is questionable if the poorer economy certain to result from the intermittent operation of boilers for the heating load in winter, assuming that the power load was taken by the central station, would not offset the saving effected through the electrification of the railroads. It is, therefore, quite certain that any regional power development that does not include also the distribution of heat will be extremely limited in its success, for with the present methods of electrical-power generation, it would never be possible to distribute electrical current for the heating of large areas.

In the United States and elsewhere all plans which follow the idea of super-power stations and of multiple production, take into account the necessary development of avaliable water-power as a source of energy for those regions lacking coal. In this connection it is not without interest to recall the recent argumentation advanced by Mr. Charles P. Steinmetz of the General Electric Company. As we have pointed out before, electricity, being a form of energy devoid of bulk and convenient for transmission, logically suggests the method of hydroelectric development. Instead of collecting and conveying a large mass of water, preserving its head by mechanical means and then generating electricity in a large and costly hydroelectric plant, from which the current is fed into a distributing net work of lines, generators with small hydraulic turbines should be distributed through the watershed. Hundreds of such small induction generating stations then would feed into the system over collect-

ing lines and a large synchronous main station—steam turbine or hydraulic, or possibly even merely a synchronous motor station—would control the voltage and frequency of the system.

To quote from Mr. Steinmetz' article in the *General Electric Review,* for 1919: "we collect the power of a watershed mechanically by elaborate hydraulic works, costing many times more than the most elaborate electric generating station, and then in a big unit convert the hydraulic, that is, mechanical power into electric power in a modern synchronous generating station. Or we burn millions of tons of coal under the steam boilers in our huge steam stations, extract 10 to 15, or possibly 20 per cent of its energy as electric power, and then pay for the condensing water to throw away the 80 odd remaining per cent of the heat energy of the fuel, while in numerous other furnaces we burn millions of tons of coal to produce heat, but waste the potential mechanical and electrical energy of this coal.

"This is not a condition to make us proud of our industrial efficiency. But it came about naturally as the result of historical development. But the high cost of the hydraulic work makes such development economically feasible only where large amounts of water power are available in fairly concentrated form, and with the increasing development of such power sites, the number of water powers capable of development by our present methods is decreasing, while most of the country's potential water powers cannot be developed by our present standard methods of hydroelectric generation, as the cost of the necessary hydraulic development, to collect the water power, is greater than the value of the power which may be collected. The only hope which can be seen for a more complete utilization of our country's hydraulic power, from the abandoned mill sites of New England to the mountain streams of the south and the west, thus lies in applying to the electric generation the same principles which have made the electric motor economically successful, that is, bringing the electric machine to the place of the power. That is, just as we place individual motors at every machine where mechanical power is required, and distribute the power to them electrically, so to place individual electric generators wherever along the water course hydraulic power is available, and collect the power of all these generators electrically."

The universality of application of electric power from a little domestic grill or flat-iron to a huge steel furnace, from a sewing machine to an electric locomotive, from a wireless telephone to a synthetic food production, seems to so fully embrace the entire struc-

ture of modern life that a community without electricity sounds an absurd anachronism. Yet, considering the enormous wastes incurred in production and usages of power and gas we can not fail to see one outstanding fact:

We need no new inventions, no new machinery to eliminate a fabulous proportion of losses incurred to-day due to lack of coördinated knowledge, coöperation and managerial ability, in short *an intelligent mastering of power production for the benefit of the community is alone capable of conserving three-quarters of our power resources increasing the productive capacity and the wealth of the country almost beyond conception.*

Sale of Power

Electric plants were first established to furnish current for light, and the operating costs and the profits of the enterprises were borne by the consumers of light. But soon it was found that the plant could be operated cheaply during the day time, provided the light consumers continued to bear the burden of the operating costs, the sale of power generated during the day representing a net gain. This was the starting point of the methods of selling electric power. With the increased use of electric light and power and electric energy becoming a commodity, innumerable systems of determining a just and logical rate charge were put forward.

The various systems of sales schedules for energy are based: either upon the principle of *unmeasured charges* which can be unrestricted or restricted by time and place or upon the principle of *measured charges* which can include demand, maximum rate of consumption, quantity, and time. The measured charges again can be based upon one or two or on all three fundamental units.

Two basic theories were developed in practice in regard to fixing the price of electrical energy sold to the consumers. One is the so-called *cost-of-service* theory which is the oldest one, and which was long held to be the only sound one in principle for rate making by public utilities, and is still apparently supported by the National Electric Light Association. Its principle is, that a public utility company is justified in charging the wholesale consumer, who is in the position to erect an isolated plant for his own purpose, only just enough to defeat any possible competition by any possible isolated private plant.[127] The revenue thus obtained may fail to cover but little more than the bare expenses. The small consumer, especially the residential consumer, gets a rate as high

as necessary to cover the remainder of the costs plus a desired profit.

The second theory is the so-called *"two-rate"* theory now adopted by the most of the public service commissions. It is based on the principle of proportioning the cost of each type of service. The proportional cost of each service plus a fair profit is borne pro rata by each individual consumer. The workings of this second, or cost-of-service, theory can be outlined in general as follows:

The central station costs are divided into two groups: (1) *variable expenses* covering expenses which rise or fall with the increase or decrease of the station's output. In that class belong all the expenses in regard to fuel, oil, water, the major part of the generating plant labor, and it also includes that portion of allowed profit which is over and above a fair interest rate on investment; and (2) *fixed expenses* which includes all the expenses independent of output and which go on day by day, whether there is a full load or the plant is idle. They include interest on investment, taxes, depreciation, obsolescense of equipment, insurance, station upkeep, salaries, etc.

These latter expenses are again divided into two parts: (a) the cost caused by each individual consumer, such as reading of meter, billing, fixed charges on meter, etc.; and (b) covers the remainder, each consumer's share being dependent on the proportional part of station—equipment necessitated by that consumer's power—demand. Thus the total charges to each consumer covers:

E the energy charge

C the consumer charge

D the demand charge (capacity or readiness charge), or

$$T=E+C+D$$

E is a flat rate of as many cents per kilowatt hours consumed as are derived by dividing the total variable yearly expenses by the total variable yearly expenses by the total kilowatt hours so sold.

C is a fixed sum per month representing the cost of a consumer to the company regardless of consumption. It is the actual tangible outlay of the company for installing, reading and accounting the particular meter.

D is the proportion of the distribution system and central station fixed expenses incurred by a said consumer. The majority of the utilities corporations make D proportional to the consumer's maximum demand, measured directly by recording wattmeters for whole-

sale consumer's, and for retail consumers it is approximated from experience. It is a common procedure to measure or assume a maximum demand of each customer and charge pro rata that proportion of foregoing fixed expenses which that maximum bears to the sum of maximum of all consumers. The opponents of this method show that *D* for any definite class of customers should be based on the degree in which that class shares in the station peak load.

In an article by Dickerman, on Comparison of Electric Light and Power Rates (*Power,* Vol. 42, p. 8, etc.) the rates for different classes of services from residential lighting to wholesale commercial consumer throughout the United States are compared. Carbo-electric as well as hydro-electric plants are included. The comparison shows that:

1 All costs, including some profits, of generation and delivery to substations is less than 1 cent probably 0.8 or 0.9 cent per kilowatt hour

2 The bulk of the schedules are based on the principle of number of hours of use of demand, either after the Hopkinson or the Wright System

3 Many companies depart from the system and provide so-called "quantity rates" not taking the connected load as basis of rate making. Such quantity rates are usually rather low

4 Schedules providing for a ratio of 4 or less between the charges to small and large consumers are enabling the corporations to make ample profits, hence ratios of 5 or 6 or more are entirely unjustified

5 Cities in the far West have more equitable rates and lower rates than the cities in the Eastern States of the United States.

Dr. John Hopkinson was in 1883 the first to suggest the use of "maximum demand" in addition to the number of "units" or kilowatt hours as absolutely essential for arriving at the cost of supplying electric energy and A. Wright in 1893 developed and patented a "demand indicator" for measuring the "maximum demand." Since then papers without number have been written on the subject of rates and every phase of it has received critical attention. But measuring simply the kilowatt-hour consumption gives no indication whatever of the load factor. The maximum demand is one of the

variable and must be determined by a method, cheap and reliable, as otherwise no logical basis of rate can be found. Measurements of the maximum demand by means of special indicators are in use but for the small minority of large wholesale consumers only, while no attempt is made to ascertain the correct maximum demand for the great majority of users of electric energy.

The residential service is no longer restricted to lighting, and with the electrical household appliances coming more and more into use, includes power service which will necessitate a material modification in the treatment of this class load. The central stations aware of this change, though obtaining their information solely from the one item of kilowatt-hour consumption, established rates for this largest service supplied by them, taking into account the variations in the amount of energy required. The load factor however is not established by any measurement but determined by observation, arriving at a close degree of approximation.

In order thus to render a logical bill for electric service the rate maker has to have recourse to makeshifts. The most usual method is to base the rate on the connected load—the total capacity of the consumer's equipment, together with kilowatt hours. The bill thus becomes a function of the customer's equipment and not of the extent of the use of that equipment. Another method is to make observations at the time of day or week when the consumer is presumed to take his maximum, and this approximation is then taken as representing the maximum demand. For lighting rates the maximum is generally approximated by being based on the number of rooms illuminated, the character of rooms is sometimes taken into account, or the area illuminated, or even the cubic content of the illuminated space.

In 1915 Alexander Dow, President of the Detroit Edison Company formulated (see *Electrical World,* Jan. 2, 1915) what had already been taken into consideration by the various rate-makers and by various makeshifts expressed in the rate charges by many of the central stations, into three main items to serve as basis for charging a given class of customers:

1 Costs varying with the number of customers served
2 Costs varying with demand
3 Costs varying with the use of energy; that is kilowatt hours sold.

The first of these items amounts to a service charge and requires no measuring. The second item requires a "maximum-demand"

meter and the third item a kilowatt-hour meter. Two points of some importance however were omitted by Mr. Dow. One is the time of the maximum demand, which to-day can be determined only by approximation, though that can be done with a reasonable degree of accuracy since the classification gives that indication, the other point omitted is the power factor. Energy used at a low power factor requires more generator space, more transformer capacity and more transmission and distribution capacity than energy used at a high power factor. It is well recognized that true power has to be separated from apparent power, as it is the reactive power of the customer's installation which affects the net work, and that alone can rightfully be charged to him.[128] To sum up the requirements necessary to serve as basis for a logical energy rate (cost-of-service system) are:

1 Kilowatt-hours alone cannot serve as basis

2 Maximum demand has also to be measured to recognize the load factor

3 Power factor should be recognized as one of the variables.

In accord with the general tendency towards standardization and simplification certain simplified tariff systems have in late years been proposed. Systems which are said to be suitable in any area of supply and whose principle is the abolishing of the "diversity factor" as well as of the "load factor." The most characteristic of these suggested systems is the so-called "postal plan" of selling power to industry and any other consumer of electric energy.

The postal principle of selling, means a fixed charge per kilowatt hour independent of maximum demand and number of customers served, taking only into account the number of kilowatt-hours sold. The idea is based upon the following argument: A two-cent stamp will carry a letter anywhere—the two cents representing the sale price of the postal service for a given unit weight of letter. The census figures show that the average cost of generating electric energy is less than one cent per kilowatt-hour; hence a uniform rate per kilowatt-hour could be established—say a one cent rate—independent of class of service—lighting, power or traction load and independent of quantity of service required. The question is whether such a plan is feasible with conditions as they are at present in the central power station industry. To-day what mostly handicaps its development—either carbo-electric or hydro-electric—is the necessity of providing its own means of transmission and distribution, which

requires a great initial capital investment with high costs of maintenance.

The postal service is that of a common carrier of the public utility order and in applying the principle of selling service for a given unit of weight for a fixed standard price, to the selling of energy, we will have to adopt the common public carrier system for the transmission of electric energy. The British super-power station plan recognizes that necessity and provides for the standardization of frequency and voltage of the main transmission and and distribution. A universal standard tariff systems, like the postal distributing systems and for an authority do deal with generation plan of selling energy, would certainly have an enormous influence on industry and will give a tremendous impetus to the use of electric energy. Power would then really become a commodity, a cheap, staple and indispensable commodity.

Conclusion

The prime function of industry is service to the community—to be rewarded commensurately with that service. Power is the basis of industry, without it industry cannot exist. Hence power is a force of prime necessity to the welfare of the community, and should be dealt with in that sense. The criterion in the generation and sale of power therefore, should not be primarily or exclusively the shareholders' profits in that specific enterprise, but should have first regard to the interests which the country and community at large have in the generation and sale of power, that is, in the availability of cheap and unlimited power. It is the question of dollars for a few or the welfare of all.

It must not be forgotten that the world order around us especialy in its economic bearings and the position of industry, have not yet fully emerged from the formative period ushered in a hundred years ago by the so-called "industrial revolution." Present day economic procedure is still mainly the product of a period when the nature of energy resources were only imperfectly known and the technology of the employment of energy only crudely developed.

In the old and still lingering order men worked with the idea that the resources of nature were inexhaustible, and their undeveloped methods and conditions were inadequate and impotent, unable to avoid large series of wastes, which are not only inexcusable with the modern means at hand, but which are responsible to society being directly connected with economic and social questions at the base of

general well being. There is still lack of scientific or even improved methods of coal mining and oil production, both cases causing enormous avoidable waste and loss, the consequences of which, are possibly, more serious in regard to oil—the ultimate exhaustion of which is in view [129] than concerning coal, while only a fraction of the hydroelectric resources, capable of replacing coal and oil, are developed. The absurdity of coal being hauled across the whole continent to move trains across the Rocky Mountains Divide, while ample hydroelectric power is close at hand means waste in effort and material. The present utilization of coal allows only a very low recovery of its energy content, in addition to which, one-quarter more coal on an average, is burned in power production than is necessary. Likewise the utilization of oil is efficient only in its refined product but most wasteful in the crude form.

Wastefulness in production in any branch of industry is not necessarily considered an evil, but rather as an asset to profit. It is found that the public can be relied upon to pay any price so long as the production cost is high enough to prevent the profits from appearing extortionate. The expense of waste in industrial production is passed over to the consumer. Prices are maintained by the wilful reduction of production, which is kept below the level of demand. The majority of industries use only half of their equipment, or otherwise stated work half-time. There is lack of coördination, and lack of proper media of distribution, with the result that competition burdens the commodities with expenses which are far in excess of the costs of production. To sell the product costs more to-day than to produce it.

The waste of labor and material, the inadequacy of distribution and inelasticity of credit form a group of causes intimately connected and mutually reactive upon each other making impossible the attainment of 100 per cent production either from industry or the utilization of the soil. This result is directly due to the lack of coördination between resources, technology and economic procedure.

In the realm of development and production free coöperation and individualistic endeavor may seem desirable, as competition appears as an effective means of progress and development at that stage. In the realm of full utilization and distribution competition fails to give adequate results, its effect is harmful and must give way to constructive mutual consideration and coördination in the interest of the community as a whole.

The "industrial revolution," which brought in the formative period now passing away, was in close interrelation with a general

world upheaval. To-day the world again is in travail out of which will arise a new world order, economic, political, and social, in which coördination of all human activity towards economy of material and human effort will be the basic principle.

The "formative period" has been the age of coal as fuel and steam as power. The new time is already outlined as the era of coal fully utilized and water as resources of energy, and electricity as power.

The inherently local nature of the generation and use of steam power prevented it from ever becoming a commodity. The contrary is true in regard to electric power. The characteristic of electric power constituting it a true commodity, the fact that it can be generated in bulk and sold in retail, the ease and flexibility of its transmission to a distance from its point of generation by means which can be extended at will, make natural the centralization of its generation. That centralization makes possible industrial efficiency with economy in material and human effort.

These results are only attainable through coördination of resources, technology, and economic procedure, necessitating a coöperative organization of the whole industry of power production, for the efficient employment of energy resources, their production and full utilization—multiple production—the generation of energy, its transmission and distribution, on the principle of service to the community.

The vital question is whether an organization so based on the principle of the common good, is to come into fact or whether the power industry which is already in the hands of large amalgamated interests shall become more and more centralized in those hands until it constitutes an absolute monopoly, holding at its mercy the entire industrial and other power requirements of the whole people. It appears obvious that the only solution furnishing escape from so undesirable an alternative would be public ownership of the resources of energy, its production, generation, transmission, and distribution. This solution alone would permit a proper and full development of water-power for hydroelectric purposes, and the complete utilization of coal and oil in the sense of multiple production, making of power a cheap and universally available commodity.

Whether such an organization should take the form of super power stations combined with by-product plants and transmission and distribution systems, following the plan outlined by me to the Hon. F. K. Lane, Ex-Secretary of the Interior, or whether it should be a coöperation between central power stations, isolated plants, coke

and gas plants, and a separately organized power transmission and distributing system, whether the management of the power production, the fuel utilization plants and power transmission and distributing systems should be in the hand of the state, or in the hand of semi-public, state-financed, public utilities corporations, or should be left to private corporations under public supervision, are questions beyond the scope of the present discussion.

One thing however is clear. In the economic conditions now arising, the principle of electricity as a commodity, the principle of common public carrier applied to the transmission of power, and the principle of multiple production for the utilization of energy sources will be the most important, if not the basic economic force in the industrial order and in the life of the people itself.

APPENDIX 1

The diagrams in Figs. 13 and 14 represent applications of the Grinevetski method of graphical analysis of the working process in a steam boiler. Briefly stated, the diagrams consist of two main curves: a heat curve TQ and a characteristic HQ, a third auxiliary curve, known as a radiation curve, being added for use in determining the influence of radiation of the incandescent fuel on the grate on the whole process. The heat curve is constructed from the temperatures of gases T as ordinates and the heat in the gases of corresponding temperature as abscissa Q. The heat developed during the combustion could be represented as a function of temperature. Assuming the following symbols:

B_h = Fuel consumed per hour in lb.;
G_b = Weight of gases in lb. per 1 lb. of fuel burned;
C_p = Average specific heat of gases (at p = const.);
T = Temperature of gases;
T_b = Temperature of furnace;
T_s = Temperature of escaping gases;
T_a = Temperature of air entering the furnace;
Q' = Heat in gases in B.t.u. at temperature T;
Q_a = Heat in gases in B.t.u. at temperature T_a;
Q = Heat of gases developed during combustion in B.t.u. per hour;
Q_b = Heat value of fuel in B.t.u. per lb.

Thus

$$Q = Q' - Q_a \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and

$$Q' = cG_bB_ht. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The specific heat of the gases could be represented as a lineal function of temperature,

$$C_p = c + \delta t, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where c and δ are constant for the fuel of given composition and definite percentage of CO_2 in gases. For variable CO_2 and different fuels, c and δ vary but slightly and for all practical use have little effect on the calculation.

Thus from equations (2) and (3) we have

$$Q' = cG_bB_h\left(t + \frac{\delta}{c}t^2\right). \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

In this cG_bB_h is constant, except in case of infiltration of air into gas passages, and at any given condition of combustion can be taken as a scale for the diagram. The expression $\left(t + \frac{\delta}{c}t^2\right)$ is an equation of a parabola, and as such can be easily plotted. Assuming c, in inches, is a scale for ordinate equal to 1° F. and w, in inches, is a scale for abscissa equal to 1 B.t.u., equation (4) becomes:

$$Q'w = \left(t + \frac{\delta}{c}t^2\right)b, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

and the method of plotting this curve is evident. It gives the heat curve TQ.

If $Q' = Q_a$, then $Q = 0$; and therefore the ordinate shall pass through temperature T_a of the curve.

From equations (4) and (5),

$$w = \frac{C}{cG_b B_h} \text{ in inches} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Referring to fuel consumption per hour to a unity when $B_h = 1$ lb., equation 6*a* is obtained

$$w_0 = \frac{C}{cG_b} \text{ in inches.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6a)$$

The application of this heat curve is apparent. The temperature of the gases T is known and, being represented in a scale b, if referred to the curve and projected on abscissa, gives the corresponding heat in the scale $w = 1$ B.t.u. Thus from the heat value of the fuel and the weight of the gases developed from its combustion, may be found the theoretical temperature in the furnace T'_b by projecting on the curve $Q_b w_0$ and reading the temperature at this level on the corresponding scale of ordinates.

The deviation of the parabola from the straight line OC indicates the variation of specific heat of gases with the change of temperature, which is considerable at the high temperatures. If

$Q_0 = B_h Q_b$ = heat available;

$Q_1 = Q'_1 + Q''_1$ = heat utilized $\begin{cases} Q'_1 \text{ by radiation;} \\ Q''_1 \text{ by convection and transmission;} \end{cases}$

Q_2 = the loss due to incomplete combustion;

$Q_3 = Q'_3 + Q''_3$ = external losses $\begin{cases} Q'_3 \text{ in furnace;} \\ Q''_3 \text{ in gas passages;} \end{cases}$

Q_4 = is the heat lost in escaping gases.

We can study graphically the heat balance as well as ascertain and locate the cause of any loss due to inefficient performance of a certain part of the boiler or furnace. Q_4 is directly shown by the heat curve, and an evaporative test supplies the data of Q_1; hence the equation of heat balance is:

$$Q_2 + Q_3 = Q_0 - (Q_1 + Q_4). \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Similarly by further graphical analysis the other elements could be ascertained.

It is useful to plot also the curve of radiation $T\theta$ which represents the equation

$$\theta = \left\{ \frac{T + 459.2}{491.2} \right\}^4.$$

In accordance with the equation of Stephen for an ideal black body, the heat transmitted by radiation is:

$$Q = \sigma F T^4,$$

where T = absolute temperature of the body, F = radiant area, σ = constant. This constant in metric units for lamp black $\sigma_1 = 4.33$ cal. per m.^{2} per hr., or 1.678 B.t.u. per sq. ft. per hr. Professor Grinevetski gives a table (see Table I) for θ at temperatures from 302° F. to 2912° F. The intersection of the radiation curve, plotted in accordance with this method, with the heat curve determines

TABLE I—VALUES OF θ AT VARIOUS TEMPERATURES *

T, Deg. Cent.	θ	T, Deg. Cent.	θ
150	320	900	18,930
200	501	950	23,370
250	748	1000	26,540
300	1,078	1050	30,650
350	1,506	1100	35,550
400	2,051	1150	41,000
450	2,732	1200	47,080
500	3,571	1250	53,800
550	4,590	1300	61,210
600	5,810	1350	69,370
650	7,260	1400	78,340
700	8,960	1450	88,150
750	10,955	1500	98,810
800	13,210	1550	110,460
850	15,980	1600	122,800

T_b, the temperature in the furnace and Q'_1, the heat utilized by radiation. In this case, like all others, the comparison of ideal conditions with those observed gives a valuable indication as to direction in which we must apply our efforts, and in most cases as well supplies us with the means of measurement. Only the analysis of the whole problem in its entirety, however, can tell whether further efforts are worth trying in practice or not.

The rule made manifest in this research on radiation could be expressed as follows: Under equal conditions of combustion the temperature of the furnace, is in direct proportion to the rate of firing.

$$B_h = \frac{\text{lb. of fuel per hour}}{\text{area of grate surface}},$$

and in inverse proportion with the intensity of radiation.

The second main curve, or characteristic, has the same heat scale on abscissa as the heat curve, but as ordinates we take the area of heating surface, H. If

k = factor of heat transmission in B.t.u. per sq. ft. per hr., and

T_k = temperature of boiler water in accordance with Redtenbacher's researches, we have,

$$k(t-t_k)dH = -dQ,$$

whence

$$\frac{dQ}{dH} = k(t-t_k). \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

This equation can be plotted very conveniently, if k is constant, and the tangent of the angle ϕ between tangent to characteristic curve and the line of ordinates, is in direct proportion to the difference of the temperature of the water in the boiler and the temperature of the gases in contact with a given section of the heating surface. Thus, with T_k and k known, the shape of the

* Values calculated in c. g. s. units.

characteristic curve is determined by the temperature of gases (abscissa Q) and is independent of the ordinate. This is a particularly convenient peculiarity, since the curve can be plotted from any initial temperature without changing its shape; a number of tangents plotted in accordance with equation (8) determines the curve. From this equation it is evident, that with the decrease of $(t-t_k)$, tang ϕ decreases and with $t=t_k$ tang $\phi=0$, and our ordinate KH of the heat curve for temperature tk will be the asymptote to the characteristic curve. If with $t=t_k$, $H=0$, and the abscissa of the characteristic curve will be on the ordinate T_b of the heat curve scale. The ordinate of the characteristic curve starts from the axis thus located, $R-R$, which determines the area of heating surface in contact with the hot gases, while the corresponding temperature of gases is represented by the distances between OQ and tQ. The scale for the heating surface area is determined as follows:

$$f=\frac{nk}{cG_bB_h} \text{ in inches.} \quad \ldots\ldots\ldots \quad (9)$$

From this we can estimate the temperature of the gases in any part of the gas passages. If $H=H_k$ (total heating surface), we know from the heat curve that $T=T_s$ and Q_4. On the other hand, if we know the various temperatures we can locate the sections of gas passages in which they are present and from the characteristic, the areas of the heating surface. If k (factor of heat transmission) is unknown, but T_b and T_s are known, the factor of heat transmission itself can be determined from equation (8).

The rate of driving the heating surface is shown by the characteristic curve. Assume

$$g=\frac{dQ}{dH},$$

for average conditions and

$$g_m=\frac{Q'-Q''}{H''-H'}$$

for the local rate of driving in B.t.u. per sq. ft. per hor. Also

$$g_m=\frac{Q'-Q''}{H''-H'},$$

which equals average rate of driving for a given portion of a heating surface.

The first equation is a tangent of the angle between a line tangent to the characteristic curve and the axis of ordinates, and the second, a tangent of an angle betwen a line normal to the same ordinate and $(H''-H')$, or

$$\text{tang } \phi=\frac{dQw}{dHf}. \quad \ldots\ldots\ldots \quad (10)$$

Since

$$w=\frac{b}{cG_bB_h},$$

and

$$f=\frac{nK}{cG_bB_h}, \quad \ldots\ldots\ldots \quad (9)$$

the equation becomes

$$g=\text{tang } \phi\times\frac{nk}{b}. \quad \ldots\ldots\ldots \quad (11)$$

This can be plotted as

$$g=\frac{y}{h}. \quad \ldots\ldots\ldots \quad (12)$$

where from $h=\frac{b}{n}$ is a scale for the rate of driving the heating surface = 1 B.t.u. per sq. ft. per hr. From equation (12) can be determined g_m for the entire boiler and furnace in which case Q'_1 should be added as radiant heat absorbed.

In determining the volume of gases, the volume V with p = constant is proportionate to the absolute temperature and evidently can be read on the ordinates of the heat curve where the scale for volumes per second in cubic feet will be

$$V\zeta=\frac{1670h_b b}{(g_b-1)B_h\zeta}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

where h_b = barometric pressure,

ζ = ratio of volumes of gas and air at the same temperature.

Thus, if h_b = 760 mm.,

$$V\zeta=\frac{1{,}260{,}000b}{(g_b-1)B_h\zeta}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13a)$$

Whence from equations (13) and (13*a*), we learn the scale for volumes of gases per second, we can determine the volumes per second for any temperature at any portion of gas passages. Consequently taking into consideration the cross-sectional area of gas passage, we can determine the average velocity of gases in the corresponding places.

APPENDIX 2

SPECIFICATIONS FOR FURNISHING AND DELIVERING BRITISH THERMAL UNITS IN SHAPE OF SEMI-BITUMINOUS COAL

Amount of Heat-Units, in Shape of Coal, Required

1. The approximate amount of heat-units, in shape of coal, required under this contract, the point of delivery and the approximate rate of shipment, is as follows:

Point of Delivery	Approximate Number of British Thermal Units Required
.....	.....
.....	.....
.....	.....

Point of Delivery

2. The price stipulated for the coal delivered at.....does cover all the work and expense incidental to or connected with the unloading, hauling, storing, and trimming of the coal in the sheds or bunkers at the various plants, to the satisfaction of the engineer.

Character of Coal Required

3. The sizes of semi-bituminous coal are to be specified as follows:

a. Run-of-mine.

b. Crushed not larger than $1\frac{1}{4}$ inches in diameter.

The size of coal, the minimum number of B.t.u. per pound, the maximum per cent of volatile matter, the maximum per cent of ash, the maximum per cent of sulphur and the maximum per cent of moisture at the different points of delivery must be as follows:

Point of Delivery	Size of Coal	Minimum Number of B.t.u. as Delivered Per lb.	Maximum Per Cent of Volatile Matter, Dry	Maximum Per Cent of Ash, Dry	Maximum Per Cent of Sulphur, Dry	Maximum Per Cent of Moisture
.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....

Causes of Rejection

4. Should any coal delivered hereunder contain more than the per cent of moisture, sulphur, volatile matter, ash, or fewer than the number B.t.u. per pound allowed above, the coal can be rejected.

Weighing

5. All the coal delivered must be weighed at the point of loading or reloading and verified by Company's Coal Inspector, the weight shown by his statement to be indisputable.

Sampling

6. Samples of coal as delivered will be taken by a representative of the Superintendent of Power. All the coal will be sampled at the time of its being delivered to the plant. The sample taken will in no case be less than the total of 500 pounds, to be selected proportionately from the lumps and fine coal in order that it will in every respect totally represent the quality of coal in consideration. To minimize the personal equation, the gross sample will be pulverized in the crusher, until none of the fragments exceed 1 inch in diameter. The fine coal will then be mixed thoroughly and divided into four equal parts. Opposite quarters will be thrown out, and the remaining portions thoroughly mixed and again quartered, throwing out opposite quarters as before. This process will be continued as rapidly as possible until the sample is reduced to such an amount that all of the final sample will be contained in the shipping cans or jars of not less than 2 pounds capacity, these cans or jars to be sealed air-tight.

Analysis

7. The sample prepared as indicated above will be forwarded to the Fuel Department chemical laboratory, where it will be analyzed and tested immediately on receipt, following the method adopted by the American Chemical Society and using a bomb calorimeter standardized against cane-sugar, as obtained from the National Bureau of Standards at Washington, D. C. A copy of the results obtained by such analysis will be mailed to the contractor upon the completion of the test, and not later than forty-eight hours after taking the sample. The report of the chemical laboratory will show:

1. The number of B.t.u. per pound of coal as delivered.
2. Per cent of moisture.
3. Per cent of volatile matter.
4. Per cent of ash.
5. Per cent of sulphur.

Should there be no question raised by the contractor within twenty-four hours after receiving the copy of the chemical report as to the figures shown by the analysis, the sample of the coal will be destroyed. In case the contractor does not abide by the results of this analysis, a second analysis from the same sample will be made, and if the discrepancy between the two analyses will be shown to be 2 per cent or less in the determination of B.t.u. per pound of dry coal, the per cent of volatile matter, the per cent of ash and the per cent of sulphur, then the data of the first analysis will be final and the cost of the second analysis shall be borne by the.....Company, and the results of such second analysis shall be regarded as final, with the exception of the per cent of moisture, which in all cases is to be taken from the results of the first analysis on which basis the number of B.t.u., as delivered, should be figured from the number of B.t.u. dry.

Basis of Payments

8. The number of heat-units in each delivery shall be calculated by multiplying the number of B.t.u. in one pound of coal as delivered, as shown by

the chemical report, by the number of pounds delivered, as determined by the actual weighing. This number of heat-units will constitute the basis for the corresponding payments.

Notice of Shipment and Arrival

9. The contractor must deliver to the Power Department the original bills of lading or manifests with each shipment of coal. No coal will be accepted unless such bills of lading or manifests are furnished.

Notice of all shipments shall be mailed promptly to the Testing Engineer. The notices shall show the numbers of each car or name of boat, with character of the coal, the weight of the coal, the date when the same was shipped. These notices shall be accompanied with the original bill of lading or manifest.

Cars

10. If cars are to be used, they shall be of a suitable size and shape for unloading, and shall meet the approval of the Superintendent of Power.

Delivery

11. In case of failure on the part of the contractor to deliver the coal at the proper plant or switch in the quantities ordered and at the rate herein specified, within.....days (Sundays and holidays included) after the date or written notice mailed to him by the Fuel Department, directing him that shipments of coal are desired, then, and in that case the.....Company shall have the right to purchase such quantity of coal in the open market as may be required, and to deduct from any estimate that may be due the contractor the additional cost of the said coal delivered at the dock, railroad station, switch or other point of delivery, where it may be required, over and above the price stipulated in the contract for coal at the point of delivery.

APPENDIX 3

EMPTYING COAL CARS INTO COAL CRUSHER—TASK WITH BONUS

Application

Coal cars of Gondolier Type containing 20 tons or more, when unloaded into crusher.

Task

A Two men in car and one operating crusher..... 0.03 hour per ton
B One man in car and one man in crusher..... 0.05 hour per ton

Conditions

1 Not more than four cars may be on the siding at once
2 When three operators are used, one will look after crusher and two will unload into hopper
3 With two operators, one will be in car and one in care of crusher. In this case, the man in charge of crusher will assist the other in changing cars and opening traps
4 If two men constitute gang, the one in charge will care for crusher. If three men on gang, the one in charge will assist in unloading
5 The man in charge will start and stop the crusher and conveyor and see that the coal is dumped in proper bunker. He will also weigh the cars, make out the time cards and change the time cards
6 This task will not apply when weather conditions are such as not to permit the men to work continuously and unhampered. It is the duty of the foreman to determine such conditions

Method

A One man takes rope and hooks on empty car
B Other man starts motor and tightens rope
C Motor pulls car ahead and out of way
D First man removes rope and carries to next loaded car
E Motor tightens rope and pulls loaded car into position
F Remove and put away rope, get sledge hammers and shovels
G Open traps, one man on each side
H Using sledge hammers, pound cars until all loose coal falls out
J Get into cars and with picks and shovels, remove rest of coal
K Shovel loose coal from track in order that car may be removed
L Close traps

Details

A—Carry rope
B—Start motor
C—Pull away empty cars
D—Carry rope to next car
E—Pull next car to position
F—Put away rope, get shovels
G—Open traps
H—Hammer till all loose coal is out
J—Shovel out rest of coal
K—Clean tracks
L—Close traps

VALUES SELECTED

No. Men	No. Tons	A	B	C	D	E	F	G	H	J	K	L
2	52	0.40	1.0	0.40	1.0	1.5	0.7	1.7	12.0	33.0	1.6	2.0
1	62	.....	.....	.....	.....	.....	.....	0.8	12.0	120.0	.....	....

SELECTED

2	1	0.40	1.0	0.40	1.0	1.5	0.7	0.8	0.1	1.0	1.6	2.0

This task will apply to two men in car.

A+B+C+D+E+F+G+(H+J)×tons+K+L

(A+B+C+D+E+F+G+K+L)×1.25. ..... 11.75

(H+J)×1.25+(1.1×1.25). 1.375

Task—11.75 (1.375×tons)

For 20 tons—38.5 min.—0.64 hour

This task will apply to one man in car.

11.75—(1.375×tons)×2)—

11.75(2.75 ×2 tons)

30 tons— 94.25 min..... 1.50 hours
40 tons—121.75 min..... 200 hours
50 tons—149.25 min..... 2.50 hours
60 tons—176.75 min..... 3.00 hours
70 tons..... 3.50 hours

For one man

Estimate 0.5 hour for 10 ton

CHECK ON TASK

The capacity of the coal conveyor is 40 tons per hour. It is evident, therefore, that the operators cannot work faster than the coal is carried away.

40 tons per hour..... 0.025 hr. per ton
0.25 hr. per ten tons

Allow 20% incidental delays
0.25 0.50 0.3 hr. per ten tons

0.3 hour per ten tons should then be our task for all cars since it applies to all containing more than twenty tons, and no cars contain less then twenty tons.

BONUS

25 per cent bonus will be paid, figured on time allowed for unloading.

When ready to start on a car, the Power Plant Clerk will issue the regular time card, form G–126, and stamp the time starting and the time of completing the job.

Complete instructions for calculating this bonus will be found in Master Set of Instructions, under Timekeeping in files at Main Office.

O. K..... Approved.....

Vice-President *General Superintendent*

APPENDIX 4

WHEELING COAL IN BARROWS FROM YARD TO COAL CRUSHER, TASK WITH BONUS

Application

This applies to a gang consisting of any number of men. A bonus of 25 per cent of time allowed to fill a bunker is paid. A bunker when filled to the average height holds about 50 tons.

Task in Man Hours per Bunker

Distance Wheeled	Hours per Ton	Hours per Bunker
10	0.255	63.8
20	0.280	70.0
30	0.305	76.3
40	0.330	82.5
50	0.355	88.8
60	0.380	95.0
70	0.405	101.3
80	0.430	107.5
90	0.455	113.8
100	0.480	120.0
110	0.505	126.3
120	0.530	132.5
130	0.555	138.8
140	0.580	145.0
150	0.605	151.3
160	0.630	157.5
170	0.655	163.8
180	0.680	170.0
190	0.705	176.3
200	0.730	182.5
210	0.755	188.8
220	0.780	195.0
230	0.805	201.3
240	0.830	207.5
250	0.855	213.8
260	0.880	220.0
270	0.905	226.3
280	0.930	232.5

Conditions

1 The men will earn or lose their bonus as a gang.

2 Each man is supplied with a wheel barrow which holds 250 lbs. coal. Also a scoop shovel style No. 5.

3 The foreman will receive bonus calculated on the time of the men. He himself does not use a wheelbarrow, but he is required

a To see that each man does his share
b To keep crusher in operating condition
c To look after conveyor buckets
d To see that men are not interfered with.

4 The boiler room foreman will see that all ashes are removed during the time when the day shift is not working. Hence, the operators may start work with the whistle and not stop until the end of the day.

5. A bunker is full when containing approximately 250 tons. It is considered full when, without being trimmed, the coal reaches within a few inches of the conveyor buckets. The Boiler Room Foreman inspects the bunker at this time and upon his approval, the time card is turned in to the office.

6 The Boiler Room Foreman at the beginning and completion of each bunker will measure the distance of the coal from the crusher and the average will be used in computing the bonus. He will also see that the next bunker is empty before starting the men to work on it. Any trimming shall have previously been done by the boiler room laborers.

7 Bonus is determined at the completion of each bunker and is figured at 25 per cent of time allowed for the bunker. Instructions for calculating this will be found under Timekeeping, in file of Master set of Instructions, Main Office. At the start of each bunker, the Power Plant Clerk is notified, and he will issue a time card (Form G–126) stamped with the time of starting. This is turned in at completion of the bunker with the names of all operators. It is immediately stamped with time of completion.

Method

Wheelbarrow from crusher to coal pile, drop barrow (A). Pick up shovel (B). Push shovel into pile, pick up shovel full of 12½ lbs. coal and throw into barrow. (Note: twenty shovelsful will fill barrow.) (C). Drop shovel and wheelbarrow to crusher (D). Dump coal into crusher not too fast, for crusher may be injured (E).

Details

A	Wheel to coal pile, drop	0.010 time per ft.
B	Pick up shovel	0.075 time per 250 lbs.
C	One shovel full of 12½ lbs	0.075 time per shovel
D	Drop shovel, wheel to crusher	0.010 time per ft.
E	Dump coal in crusher	0.150 time per 250 lbs.

Let X = distance wheeled constant.

Synthesis

(A+D)X+B+E+20C = Time allowed per barrow
0.02X+0.075+0.150+1.500 = Min. per barrow
0.02X+1.725×8 = Min. per ton
0.0025X+0.23 = Hours allowed per ton

Approved.....
General Superintendent

O. K.....
Vive-President

FOOTNOTES

[1] See Danger of Fuel Famine by Walter N. Polakov, in *Industrial Management* May, 1917. Editorial in the same magazine in September, 1917. Report of May 19, 1917, to the Speaker of the House of Representatives the Federal Trade Commission. Will There Be a Fuel Famine, *The Literary Digest* for June 16, 1917, *Coal Age,* July 14, 1917, editorial by the author. *Utilities Magazine* for August, 1917. *Electrical World,* December 8, 1917. *Forbes Magazine,* December 8, 1917.

[2] Dr. H. A. Garfield's supplementary statement, January 17, 1918.

[3] *New York Times,* January 6 said: "Shipping men yesterday were informed by the authorities of the port of New York that there was no anchorage room in the harbor, and that this situation would prevail until some of the vessels could get coal to enable them to sail." Also another paper records that "there are about 150 steam ships detained in the New York Harbor because of the lack of coal."

[4] Order of the United States Fuel Administration to stop production for five days and five Mondays. Later it was modified and operation was resumed a few days before it was originally ordered.

[5] *Journal* of The American Society of Mechanical Engineers, July, 1918, Part 2, page 608–609.

[6] D. M. Meyers, *Transactions,* The American Society of Mechanical Engineers, Volume 39, page 679 and 687. V. J. Azbee, *Transactions,* The American Society of Mechanical Engineers, Volume 38, pages 717 and 748.

[7] Dr. Theodore Hertzka,—Die Gesetze der socialen Entwicklung—"615,000 workingmen are only 12.3 per cent of the population of Austria capable of work, exclusive of all women, as well as males under 16 and over 50 years of age. If all the 5,000,000 men were productively engaged, each of them would need to work only 36.9 days per year, in order to produce the necessaries of life for 22,000,000 people. Including all the articles of luxury all present wants of Austria's population will be satisfied in 60 days of work per year, or working 300 days per year, each day only 2½ hours would be required without even considering improvements in productive methods."

[8] A. Bebel—Woman under Socialism—New York, 1904, page 278.

[9] H. L. Gantt.

[10] C. P. Steinmetz—America and the New Epoch—Harper Bros., New York, 1916, page 149.

[11] Charles Ferguson—The Revolution Absolute—page 195.

[12] Prof. Irving Fisher, *Review of Reviews,* February, 1910.

[13] Walter N. Polakov—Valuation of Industrial Properties vs. Valuation of Industrial Methods. *Transactions,* The American Society of Mechanical Engineers, Volume 38, page 1297.

[15] George Willis Cooke—Scientific Management—*The Call* (New York) August 24, 1911.

[16] Prof. Malcolm Keir in the *Scientific Monthly,* October, 1917.

[17] Charles Ferguson—The Revolution Absolute—page 209.

[18] Bacon—Novum Organum—paragraph 17: "The *form* of heat or the form of light, therefore, means no more than the law of heat or the law of light."

[19] Ibidem.

[20] René Descartes—Discourse of Methods and Mediations.

[21] Op. citata.

[22] H. L. Gantt—Work Wages and Profit—New York, 1913, page 41.

[23] Walter N. Polakov—Valuation of Industrial Properties vs. Valuation of Industrial Methods—*Transactions,* The American Society of Mechanical Engineers, Volume 38, page 1297.

[24] See author's discussion of An Analysis of the Principles of Industrial Management, by T. G. Roberts, U. S. N. in the *Transactions* of the Society of Naval Architects and Marine Engineers, New York, for 1917, page 276.

[25] H. L. Gantt—Industrial Leadership—Yale University Press, 1916, page 39.

[26] Walter N. Polakov—Planning Power Plant Work—*Bulletin* Taylor Society, 1916, Volume II, No. 6.

[27] Walter N. Polakov—Standardization of Cost of Power—*Transactions,* The American Society of Mechanical Engineers, Volume 38, pages 581–598.

[28] Notably those of H. L. Gantt—*Transactions,* The American Society of Mechanical Engineers, Volumes 37, 38 and 39.

[29] August Bebel—Woman under Socialism—page 278, New York Labor News Co. 1904.

[30] "Famous engineer James Nasmyth of Patricroft, the inventor of steam hammer, is quoted by L. Horner in his report for Oct. 1852, substantially as follows: The public is little acquainted with the immense increase of motive power obtained through changes of system and improvements. The machine power of the district of Lancashire was for almost forty years under the pressure of timid and prejudiced traditions. But now the engineers have been happily emancipated.

Condensed steam engines were put into operation pretty generally after 1848; piston velocity was increased from 220 feet per minute as was regulated heretofore to 300 and 400 feet per minute; Woolf's "Double Cylinder Machines" brought the question of fuel into the foreground. K. Marx in Volume III of "Capital" (pp. 117, etc.), says: "The Cornish and the double cylinder machines furnished one horsepower per hour for every 3½ or 4 pounds of coal, while the machines in the cotton districts generally consumed 8 or 12 pounds per horse power an hour. Such a marked difference induced the manufacturers and machine builders of Nasmyth's district to accomplish by similar means just such extraordinary economies as were then the rule in Cornwall and France, where the high prices of coal had compelled the manufacturers to restrict this expensive branch of their business as much as possible. This led to some very important results. In the first place, many boilers, one-half of whose surface remained exposed to the cold outer air, in the time of high profits were covered with thick layers of felt, or brick and mortar, and other materials, by which the radiation of heat, which had been generated at such high cost, was prevented. Steam pipes were protected in the same way, and the cylinders were also surrounded by felt and wood. In the second place, high pressure came into use. Hitherto the safety-

valve had been weighted only so slightly that it opened at 4, 6 or 8 pounds of steam pressure per square inch. . . . in many cases the same steam engine, which yielded 50 horse powers at the time of the limited speed of 220 feet per minute, yields now more than 100 horse powers. The highly economical results of employment of high pressure steam in condensing machines, and the far greater demands made upon the old machines for the purposes of business expansion, have led in the last three years (written in Oct., 1852) to the introduction of pipe-boilers, by which the cost of steam generation is again considerably reduced."

It is extremely interesting to note in this connection that only partly due to new inventions and chiefly due to better use of the existing equipment and better power transmission, this progress enabled manufacturers to expand production without additional motive power. According to Redgrave's Report, Factory, Oct., 1852, p. 58., these measures as applied to a factory produced following result: "In October, 1840, his firm employed 600 laborers, of whom 200 were less than 13 years old. In October, 1852, they employed only 350 laborers, of whom only 50 were less than 13 years old. The same number of machines, with very few exceptinos were in operation, and the same amounts were paid in wages, in both years . . ."

While this seems like throwing into unemployment a large proportion of men, an economist takes a view that: "According to the degree of this expansion the capitalist will be enabled to employ a part of his former laborers under the new conditions, and eventually all of them or more, in other words, they will be enabled to produce the same or a greater mass of profits." (Capital, Vol. III, p. 271.)

[31] See British Reconstruction Committee Interim Report on Electric Power Supply in Great Britain, 1917.

[32] "The amplest application of motor powers and the best machinery and implements, the utmost subdivision of labor, and the most efficient combinations of labor-power will carry production to such pitch that the hours of work can be materially reduced in the production of the necessaries of life. Among the motor powers that are coming into application, electricity will, according to all appearances, take a decisive place. Capitalist society is now everywhere engaged in harnessing it to its service. The more extensively this is done the better. The revolutionising effect of this mightiest of all powers of Nature will but all the sooner snap the bonds of society and open the door to Socialism. But only in the future society will electricity attain its fullest and most widespread application."—A. Bebel—op. Cit.

[33] J. W. Ledoux, Presidential Address, *Proceedings* of the Engineers Club of Philadelphia, Volume XXXIII No. 2, Paper 1161.

[34] H. L. Gantt—Training workmen in Habits of Industry, and Coöperation —*Transactions,* The American Society of Mechanical Engineers, Volume 30, page 1637.

[35] Industrial Leadership—H. L. Gantt—Page 53.

[36] A. Mitchell Palmer, Alien Property Custodian in Philadelphia Speech, November 8, 1918.

[37] Ch. Ferguson in *Stevens Indicator.* Vol. XXXIV, No. 1, 1917.

[38] The Carnegie Foundation for the Advancement of Teaching, Bulletin No. 11 by Charles R. Mann, 1918, pages 107–8.

[39] Sidney Webb—The Works Manager To-day—New York, 1917.

[40] Compare it with triple formula of organized workmen:

"First: That work shall overtax none.

"Third: That work shall be as productive as possible."

[41] See *Journal* of The American Society of Mechanical Engineers, authors discussion.

[39] James L. Cowles—Postal Plan. G. P. Putnam's Sons, 1905.

[42] The Location of Power Plants by I. M. Kearns of the Boston Edison Company.

[43] Discussion of I. Moultrop's paper on Modern Central Station Design by Mr. G. H. Stott.

[44] Report on Electric Power Situation in the Philadelphia District to the Emergency Fleet Corporation, U. S. Shipping Board by Walter N. Polakov.

[45] The Barton Power Scheme—The *Electrical Review,* Jan. 8, 1915.

[46] The Interborough Rapid Transit Company, 74th Street Station, New York.

[47] R. J. S. Pigott—Graphic Method of Analysis in The Design and Operation of Steam Power Plants—*Transactions,* The American Society of Mechanical Engineers, Volume 38, page 6870.

[48] R. H. Smith—Commercial Economy in Steam and Other Thermal Power Plants. Chapter VIII London, A. Constable & Co., Ltd., 1905.

[49] Ibidem.

[50] *Transactions,* American Institute of Electrical Engineers, Volume II, page 1619.

[51] See also Wm. Kent "Bookkeeping and Cost Accounting for Factories," pages 208–12 and Leafax, 30, Power Plants 1; 7–14, January, 1917.

[52] Prof. Thorstein Veblen—The Modern Point of View and the New Order.

[53] W. C. Mitchell—History of The Greenback—Page 390.

[54] Commercial Economy in Steam Power Plants, A. Constable & Co., London, 1905—Pages 3 and 4.

[55] Ch. Ferguson, *Stevens Indicator,* Volume XXXIV, No. 1, 1917.

[56] See *The Evening Sun* (New York) Dec. 4, 1918.

[57] Since the coal operators assumed more independent attitude and generally refuse to sell coal on specifications or with any penalties.

[58] *City Record* (New York) 1910, also Report on Preventable Wastes and Losses in the Power and Heating Plants of the Municipal Government of New York City, No. 1, Dept. of Water Supply, Sept 16, 1909, and Feb. 10, 1909.

[59] See Preface to French Edition of Taylor's Shop Management.

[60] Interesting, though as yet singular resolution was adopted by British Engineers: ". . . this, like most other questions, must ultimately be settled in accord with the common interest, and believing as we do in the wisdom contained in the utterance of the late Lord Derby that 'the greatest of all interests is peace,' we are willing to leave the matter to the arbitrament of a public and *impartial authority, aided by technical knowledge* from each side."—Amalgamated Society of Engineers, 46th Annual Report, London, 1897, page VII.

[61] Louis D. Brandeis said: "Labor must have throughout an opportunity of testing whether it is the whole truth. Labor must not only be convinced of the industrial truths—which scientific management is disclosing—but must also be convinced that those truths are consistent with what may be termed human truths. Is the greater productivity attained clearly consistent with

the health of the body, the mind, and the soul of the worker? Is it consistent with industrial freedom? Is it consistent with greater joy in work, and generally living? These are questions which must be answered in the affirmative, and to the satisfaction, not of a few, merely, but of the majority of those to be affected." Taylor Memorial Meeting, Philadelphia, Pa., 1915.

[62] Count Okuma, one of the shrewdest statesman of Japan.

[63] Lord Leverhulme, noted English manufacturer, worked out from his experience a formula which he puts in these words: "Labor plus capital minus good management means failure. Labor plus good management minus capital may spell success."

[64] See—Labour and The New Social Order by Arthur Henderson, M.P.

[66] Quoted from January, 1919, issue of *"Reconstruction."*

[67] We also occasionally hear of workmen willingly extending their working day by insisting on overtime work. This, obviously is not due to lack of desire to get home early, but to a necessity to bring the income in balance with ever increasing cost of living.

[68] The Works Manager To-day, page 15, chapter 11—Sidney Webb. New York, Longmans, Green and Co., 1917.

[69] Reproduced from Ch. S. Myers, M.D., Sc. Di., F.R.S.

[70] In Belgium, Russia, and other countries where Ministries of Public Education studied the fatigue of school children, the week is broken on Thursday and afternoon is given as a holiday to promote the good work.

[71] News item: "Motormen of Westchester Railway Company went on strike demanding increase of wages from $300 to $350 per month, making their pay equal to this of locomotive drivers." Compare this with an advertisement in *Mechanical Engineering,* The Journal of The American Society of Mechanical Engineers, August, 1919: "Assistant Professor experienced in teaching mechanical or electrical engineering subjects. Location California; salary $2,000 per year," and "Detail Draftsman: young man with good training and shop experience preferably one capable of making sketches and details from machined parts of automatic book-binding machinery. Location Westchester County; salary $30 per week." Compare $4,200 of motorman with $2,000 of professor and $1,560 of draftsman and reflect . . .

[72] Washington, June 3—"Coal needs this year will be 100,000,000 tons in excess of production"—News item.

Also see author's Grave Danger of Fuel Famine, page 276, *Industrial Management,* May, 1917, and Open Letter to Secretary Lane in September, 1919, *Industrial Management.*

[73] See also "Capital" Vol. III by K. Marx, 1909, C. Kerr, Chicago, pages 15 to 120.

[74] "While the constitution (English) had increasingly taken on Democratic forms the reality underlying those forms has been increasingly plutocratic"—Cardinal Bourne. De te fabula narratur!

[75] "After the researches of Quetelet in Brussels, Farr in London, Schwabe in Berlin, Villermé and Benoison de Chateaneuf in Paris, it is no longer possible to doubt that the maximum of birth takes place among the poorer class, and that poverty itself is an irresistible inducement to an abundant and disordered birth rate." "The long working days of 12 hours make their intellectual improvement impossible, and compel them to seek their sole enjoyment in those of the senses . . . persuaded that no endeavor will better their condition, they are necessarily impelled to a great fecundity." F. Nitti "Population and the Social System." London, 1894, pages 153, etc.

[76] "It is not the lowest, but the highest-paid labor, with scientific management and machinery, which gives cheapest products." Andrew Carnegie.

[77] The same situation apparently prevails in England: "The workers . . . subjected sometimes to *irritating mismanagement* and anxious about the future, tend to be political leaders. They (workers) too are questioning the whole system of society."—Cardinal Bourne. Also see the President's Mediation Commission Report.

[78] "Standards that fail to distinguish between personal and material and that ignore the sacredness of human life, are without meaning as factors in the ultimate solution of industrial problems." Hon. W. L. Mankenzie King in *Industry and Humanity,* Boston, 1918, page 83.

[79] Mr. F. Gilbreth proved by his chronocyclegraph that a well-educated executive wastes less motion, learns quicker, and works with greater precision at unfamiliar operations than an operative who has not had the advantage of well-balanced education.

[80] *The Globe and Commercial Advertiser* (New York), Nov. 4, 1918. "In order to discover what relation undernourishment bore to poor work in school, all the children were weighed once a month. In rating the children as normal or underweight for their age, the chart of measurement and weight found in the Ninth Year Book of the National Society for the Study of Education, Part 1, Health and Education by Thomas Denison Wood, A.M., M.D., 1910, was used. One thousand one hundred and seventy children were classified and their weight record was compared with their class standing at the end of May. There were 825 pupils rated as normal, 70 per cent of the school; 345 were underweight, 30 per cent of the school. 'The underweights,' says the report, though forming 30 per cent of the school gave but 27 per cent of the successful pupils at the end of May, yet they provided 43 per cent of those who had not done satisfactory work. The 70 per cent of normal children gave but 56 per cent of the failures. Taking the normal child as a class by themselves, 88 per cent had done satisfactory work, and 12 per cent had a poor rating, while 22 per cent of the underweight children were rated as unsatisfactory. *In other words, the underweight child has almost twice as many chances of failure as the normal child.*"

Also in *New York Times,* August 4th, 1919, we read: "From 3,000,000 to 6,000,000 American children are not getting enough to eat because their parents are unable on their present incomes to buy sufficient food, said a statement issued to-day by the Children's Bureau of the Department of Labor. These are the children, the statement said, who are often pronouncd by parents and teachers 'delicate,' 'ailing,' 'lazy,' or just 'plain ornery,' although their true affliction is malnutrition.

"The number of school children in the United States who are not getting sufficient food was placed at from 15 to 25 per cent, while this was said to be true of one-fifth of the children attending school in New York City."

[81] Quoted from the Presidential Address, The American Society of Mechanical Engineers, December, 1918.

[82] Cardinal Bourne, Archbishop of Westminster, said in his pastoral letter of February 10th, 1918: "The effect of competition uncontrolled by morals has been to segregate more and more the capitalist from the wage-earning class and to form the latter into a proletariat, a people owning nothing but their labor power."

[83] "Paris, March 31st, 1919. The commission on international labor legisla-

tion has concluded its report and has drafted nine clauses for insertion in the treaty of peace . . . 'Every worker has a right to a wage adequate to maintain a reasonable standard of life, having regard to the civilization of his time and country . . .

" 'A weekly rest, including Sunday or its equivalent for all workers . . .

" 'Limitation of hours of work in industry on a basis of eight hours a day or forty-eight hours a week . . .' " From London Times—Public Ledger.

[84] Adam Smith "Wealth of Nations," London, 1776.

[85] Federalist, LXXXIX, London.

[86] In 1894 Trade Unions with 573,000 total membership insisted on piece work, 140,000 recognized piece work (713,000 members) and only 290,000 insisted on time work; this chiefly because of the nature of the work, such as Amalgamated Society of Engineers. See S. & B. Webb "Industrial Democracy."

[87] David Lloyd George's apology to medical examiners confirmed that half of the British recruits became physically unfit under the prevailing conditions of industrial employment. In the United States about 25 per cent of drafted soldiers were illiterate.

[88] "Principles of Economics," 3d Edit. London, 1895, Book IV, Chap. VII, page 311.

[89] This principle was recently recognized also by some progressive managers of other industries. *The quality of work* can easily be made a basis for extra compensation over and above guaranteed wage for motormen, bakers, chemical workers, papermakers, gas producers, etc.

[90] Cardinal Bourne, quoted before, said: "During the war the mind of the people has been profoundly altered. Dull acquiescence in social injustice has given way to active discontent. The very foundation of political and social life—our economic system being sharply scrutinized, and this not only by a few writers and speakers, but by a very large number of people in every class of life, especially among workers." *New York Times*—Feb. 10, 1918.

[91] Profit sharing and Labor Co-partnership in the United Kingdom. 1912.

[92] Authority: "Profit Sharing" H. P. Kendall and others, Harper & Bros. 1918.

[93] A. W. Burritt and others, Profit Sharing, etc., page 174.

[94] Existing practice of the T. A. & S. Fe may further be illustrated by the following standard schedule:

POWER PLANT OPERATION
Standard Schedule
.....Shops

For efficient and economical performance in the operation of Power Plant at .....bonus will be paid monthly to the Power Plant Employes according to efficiency determined by the following factors:

Item	Standard	Rel. Val.
1—Pounds of coal per boiler hour (per twelve months average)		6
2—Hours labor per boiler hour (monthly actual).....		4

The amount of fuel delivered to the Power Plant, as shown on Storekeeper's records, is considered as the fuel consumption for the period considered.

The amount of labor is to be the total hours employed in supervision and

operation of the Power Plant, including the handling place and keeping Power Plant and surroundings in proper condition.

Boiler hours to be total hours boilers are in actual operation during the period considered.

This schedule is based on ..... coal, and if other fuel is used the equivalent value is as follows:

1 Ton ..... equivalent to ..... tons .....
2 Ton ..... equivalent to ..... tons .....
3 Ton ..... equivalent to ..... tons .....

The average efficiency is determined by multiplying the efficiency attained on items (1) and (2) by their relative values, dividing the sum of their products by 10.

This schedule further provides that the cost of (three months average) all repairs (labor and material) to all machinery in the engine and boiler room, and all supplies such as oil, waste, etc., be maintained monthly for $.....

For each one per cent the average cost is below this figure, 1 per cent of the bonus earned by the engineers in items (1) and (2) will be added and will be apportioned as follows: 60 per cent to the Chief Engineer and 40 per cent divided among the other engineers according to the wages earned.

[95] See *National Engineer,* September, 1919, discussion of Two-rate Wage.

[96] Described in *Power,* April 2nd, 1918.

[97] Described in A. E. R. A., February, 1918.

[98] Address before Taylor Society at Annual Meeting, N. Y., Dec. 8-9, 1916, also *Transactions,* The American Society of Mechanical Engineers, Volume 35, page 359, paragraph 30.

[99] The results of two and one-half years of practicing this plan claim 18.5 per cent fuel saving but only 50 per cent of it, *i. e.,* 9.25 per cent is "due to the efforts of the employees," the rest of the saving being brought about through physical improvements. These meager results (the present saving in fuel cost is 8.75 per cent) are nevertheless higher than some of the plants adopting reward-payment based on similar misconception, can claim.

[100] See *Commerce Monthly,* June, 1920, article The Normal Business Cycle.

[101] In *Industrial Management* for April and July, 1918, *Electrical World* for January 5th, 1918 and in *Transactions* of The American Society of Mechanical Engineers for 1913.

[102] Pennsylvania Electric Association—Eighth Annual Convention, Bedford Springs, Pa.—Sept. 8–10, 1915.

[103] T. A. P. & P. I.—Spring Meeting, Dayton, Ohio. May, 1918—also "Paper," Volume 11.—Addresses by G. Williams and W. N. Polakov.

[104] The first requisite toward effective fuel economy is to secure coöperation between owners, managers, and the men who fire the coal. Mechanical devices to increase efficiency in the use of coal can not produce satisfactory results unless the operators who handle them are impressed with the importance of their duties." Secretary Lane's Annual Report, 1919.

[105] Machinery versus Trained Brains—*Industrial Management,* Sept., 1919.

[106] "It is not essential for the plant manager to be a fuel expert (for he can always secure services of a recognized consulting engineer), but he should be familiar with the instruments that give a check on the daily operations. It is a mistake not to provide proper instruments, for they guide the

firemen and show the management what has taken place daily. Instruments provided for the boiler room manifest the interest taken by the management toward conserving fuel. It indicates coöperation and encourages the firemen to work . . . to increase the efficiency." Report of the Secretary of the Interior, 1919, page 10.

[107] From a paper before the American Boiler Manufacturer's Association, Buffalo, N. Y., 1919.

[108] See G. H. Barrus *Boiler Tests,* New York, D. Van Nostrand, 1900.

[109] Since this was written D. V. Merrick published in his book Time Studies for Rate Making complete instruction cards on unloading soft coal, Figures 68 and 69 on page 205.

[110] *Transactions,* The American Society of Mechanical Engineers, Vol. 35, pages 353, 354.

[111] At Dayton, Ohio, May 16, 1918.

[112] A. F. Graves—November, 1917, issue of *Strathmorean.*

[113] New York Central Railroad Company, September 21st, 1916.

[114] See "Commercial Steam Power Economy," by R. H. Smith, London, 1905.

[115] Says the *London Economist*: "Any attempt to achieve full efficiency in production and distribution which does not have as its paramount aim the cheapening of the product to the consumer will fail, and deservedly fail, through the revolt of the consumer."

[116] Testimony of H. L. Gantt on Cost of News Print, 1917, before Federal Trade Com.

[117] *Industrial Management,* Nov., 1918, page 397.

[118] Page lecture series, Sheffield Scientific School, Yale University, 1915. By H. L. Gantt.

[119] Wm. Kent, "Cost Accounting." Lefax data." G. Ch. Harrison—Accountancy to Aid Production, etc.

[120] H. G. Stott of the Interborough Rapid Transit Company, N. Y., in discussion of T. E. Moutrop's paper (*Proceedings,* American Institute of Electrical Engineers), "Modern Central Station Design" said: "59 per cent of the machinery in a lighting plant operates only 300 hours per annum, so that it becomes most important to keep down the first cost, for assuming that a plant cost $125 per kilowatt capacity then the interest and depreciation charges upon the portion of it used for peak load would amount to 5.2 cents per kilowatt hour, or probably five times as much as the operating cost."

[121] *Independent Operation:*

Full output of 13,300,000 kilowatt hours @ 2.7 pounds = 35,910,000 pounds of coal.

Parallel Operation:

Fractional load 10,000,000 kilowatt hours @ 3.5 pounds =	35,000,000	pounds
Fract. purchased 3,300,000 kilowatt hours @ 2.1 pounds =	6,930,000	pounds
Total coal	41,930,000	pounds
Independent operation	35,910,000	pounds
Waste of coal	6,020,000	pounds

To make parallel operation equally conservative in coal consumption 3,300,000

kilowatt hours must be generated with only 910,000 pounds of coal, this of course cannot be done by the public utility company.

[122] *Electric Railway Journal,* Dec. 18th, 1915, etc.

[123] Acknowledgment hereby is made to Prince E. Lasarovich who assisted the author in compilation some of the data used in this chapter.

[124] "About two-thirds of the coal consumed in the United States goes into the production of power which is divided almost equally between the industries and the transportation systems; about one-sixth is used as a raw material for making substances employed indutrially, such as mentallurgical coke . . . One-sixth approximately is employed for heating homes and other buildings." *Bulletin* No. 102, U. S. National Museum, part 4, page 6.

[125] The unfinished products of coal tar industry alone include nine principal groups: (1) Dyes, (2) Color lakes, (3) Photographic developers, (4) Medicinals, (5) Flavors, (6) Perfumes, (7) Penolic Resins, (8) Tanning materials, (9) Explosives.

To mention a few best known: alizarin, indigo (synthetic) creosote, naphthalene, benzol, toluol, tylol, benzoate of soda, salycilic acid, aspirin, acetanilid, antipyrine, salol, saccharin, carbolic acid, pyrogallol, rhodinol, methyl, acetophenon and other perfumes.

Due to the undeveloped state of this industry in the United States until very recently we entirely depended on imported intermediates.

DYE PRODUCTION OF THE WORLD
From Coal By-Products
(From United States Tariff Commission Report No. 11)

1	Germany	$68,300,000
2	Switzerland	6,450,000
3	Great Britain	6,000,000
4	France	5,000,000
5	United States	3,000,000
6	Austria	1,500,000
7	Russia	1,000,000
8	Belgium	500,000
9	Netherland	200,000
10	Other countries	200,000
	Total	$92,150,000

Conditions before the war as given by T. H. Norton, Dept. of Commerce, Spec. Agents Series No. 96, page 30.

[126] Messrs. Ramsburg and Sperr presented in a paper before a meeting in 1917 of The American Society of Mechanical Engineers the following calculations in reference to coke making alone:

BY-PRODUCT YIELDS FROM COAL SUCH AS IS NOW USED TO MAKE FIRST-CLASS BY-PRODUCT COKE IN THE MIDDLE STATES DISTRICT
PER TON OF COKE MADE
85 Per Cent High-Volatile, 15 Per Cent Low-Volatile

	Fuel-Value Equivalent, lb. of Coal
Surplus gas. 9,000 cu. ft., 550 B. t. u. per cu. ft.	
Used as fuel	350

		Fuel Value Equivalent lb. of Coal
	Tar. 12 gallons. Used to make Creosote oil, pitch, lampblack, various oils nad dye materials	133
To make 1 ton of Furnace Coke, 1.4 to 1.5 tons Coal are required.	Ammonium Sulphate. 33 lb. (or, in form of 25 per cent ammonia liquor, 33 lb.). Used for fertilizer, for refrigeration, and for nitric acid and other chemical manufactures.	(No fuel equivalent)
By beehive coking, the by-products wasted have a fuel value equivalent to 625 lb. of coal.	Benzols (as light oil) 4.5 gallons. Used for explosive bases, motor fuel, dye-material bases, phenol and other chemical manufacture, and as a solvent and cleanser	42
	Coke Breeze. 120 pounds. Used as fuel.	100
	Total	625
	Add coal equivalent wasted in beehive oven	200
	Total economy of by-product oven per ton coke	825

This table shows a total fuel saving of 825 pounds of coal per ton of furnace coke. The fuel value of the gas is put as against raw coal, B. t. u. for B. t. u. There is a further saving in the blast furnace of 200 pounds of coke per ton of beehive coke formerly used. Figured back on a coal basis, these 200 pounds of coke represent 282½ pounds of coal at the beehive oven, so that the total saving amounts to approximately 1,100 pounds of coal—0.55 ton—for each ton of by-product coke made in the modern plant. Since the ovens added from January 1, 1915, to 1918 will produce practically 16,200,000 tons of coke per annum, it follows that they will save annually the fuel equivalent of 9,000,000 tons of coal.

[127] In the legal opinion of Louis D. Brandeis July 10, 1913, he said: "The mere fact that in the case of the wholesale customer for electric energy the public srvice company would be exposed to the competition of a possible isolated plant; whereas in the case of the retail customer there is no possibility of his supplying himself, does not afford any legal justification for difference in charge. In other words, the possibility of competition is not to be taken into consideration in determining the reasonableness of the classification."

[128] In this regard the formula given by Professor Arno may be mentioned. The complex load consists of true and apparent power.

[129] Director of Bureau of Mines estimates the life of available oil supply between 20 and 25 years.

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